Influence of the Fukushima Daiichi Nuclear Power Plant accident as determined by results of environmental radiation monitoring in Kyoto

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We have been continuously observing absorbed dose rates in the air at seven environmental radiation monitoring stations and have carried out analyses of radionuclides in various environmental samples, including deposited materials, soil, plants, and fish, in order to examine the influence on the environment of the nuclear power plants located in the adjoining Fukui Prefecture and of the global radioactive fallout. In our assessment, cesium-137, cesium-134, and iodine-131 were detected in certain types of vegetables and fish collected in Kyoto Prefecture after the Fukushima Daiichi Nuclear Power Plant accident (FDNPPA). The concentrations were considerably lower than 100 Bq/kg. In addition, silver-110m was detected in collected turban-shell samples. The concentrations of these four radionuclides were sufficiently low so that public exposure from ingestion would be significantly lower than 1 mSv per year. The influence on Kyoto Prefecture from the FDNPPA appears to be less than 10% of that from the Chernobyl NPP accident (CNPPA), as indicated by our comparison of the deposited amount of Cs-137 and the concentration of Cs-137 in environmental samples taken after both events.

Key Words: *radioactive cesium, radioactive fallout, soil, seawater, foods*

1. Introduction

We have continuously been observing absorbed dose rates in the air, and we have carried out analyses of radionuclides in various environmental samples, in order to examine the influence on the environment of the nuclear power plants located in the adjoining Fukui Prefecture, and of the global radioactive fallout. A nuclear accident at Fukushima Daiichi Nuclear Power Plant (FDNPPA), which is situated about 550 km northeast of Kyoto, occurred on 11 March, 2011.

The present paper addresses the influence of the FDNPPA as determined by the results of our monitoring in Kyoto Prefecture, since assessment of the influence is extremely important for future environmental radiation monitoring as well as dose estimation.

2. Materials and Methods

Absorbed dose rates in the air were observed outdoors with a NaI(Tl) scintillation detector.

Deposited material was collected continuously in a basin with an area of 5,000 cm^2, and the sample was concentrated by evaporation each month. Surface soil and sea-sediment were dried, ground, and sieved. Twenty liters of seawater were treated by adsorption with AMP, and precipitation with hydroxide and sulfide. Mugwort, pine-needles, dried tea-leaves, shiitake-mushrooms, Japanese stingfish, horse-mackerel, and turban-shell were concentrated by ashing. There was no special sample preparation for unpolished rice. Sample weights of plants and fish were mainly between 2 and 3 kg.

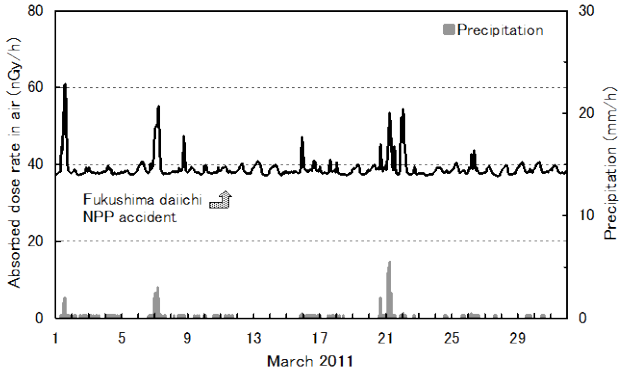

Fig. 1 Variation in absorbed dose rate in air in Kyoto in March, 2011.

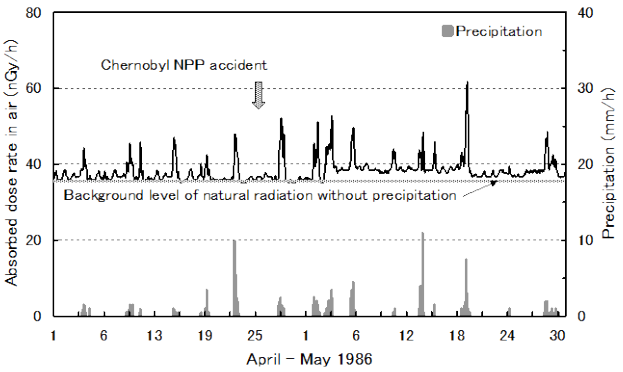

Fig. 2 Variation in absorbed dose rate in air from April to May, 1986.

Concentrations of individual gamma-emitting nuclides in each sample were determined from gamma spectrometry for 80,000 seconds using a Ge detector. The minimum limits of determination of Cs-137 in these samples were approximately 0.03 Bq/m^2 for monthly deposited amount, 0.5 Bq/kg for surface soil and sea-sediment, 1 mBq/L for seawater, and 0.02–0.06 Bq/kg for the other samples.

3. Results and Discussion

(1) Absorbed dose rates in air

The absorbed dose rates in the air, which were observed at all stations from 11 March to 31 December, 2011, ranged between 27 and 139 nGy/h. This result is normal, since the range for the 10 years from April 2000 to March 2010 was 18–146 nGy/h, with the variation being due to meteorological conditions.

Figure 1 shows the variation in the dose rate observed in Kyoto in March, 2011. It is clear from this figure that the level of the dose rate without precipitation did not change after the FDNPPA, while the dose rate increased due to precipitation. In addition, the dose rate showed diurnal variations in accordance with the concentration of short-lived radon progeny in surface air from March 12 to 14 and from March 28 to 31, when only slight precipitation was observed[1)]. Figure 2 shows the variation in the dose rate observed from April to May, 1986. After rainfall stopped on May 3, the level of the dose rate did not return to the level that had been observed before the rainfall. The level of the dose rate became about 4 nGy/h higher after May 3, slowly decreased, and then recovered within a few months. This is because rainwater on May 3 included not only natural radionuclides such as radon progeny but also relatively-long-lived radionuclides that had arisen from the CNPPA[2)]. It is evident from Figs.1 and 2 that the influence, on Kyoto

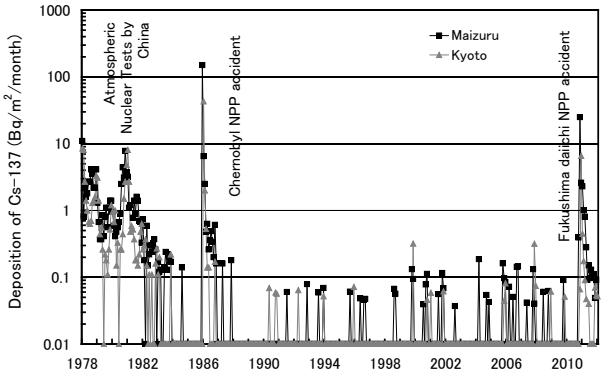

Fig. 3 Variations in monthly deposited amounts of Cs-137 in Maizuru and Kyoto.

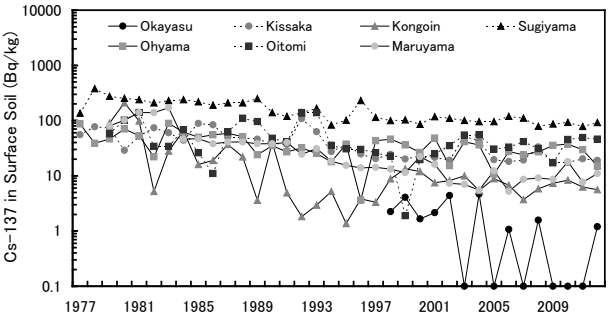

Fig. 4 Variations in concentration of Cs-137 in surface soil from 1977 until 2012.

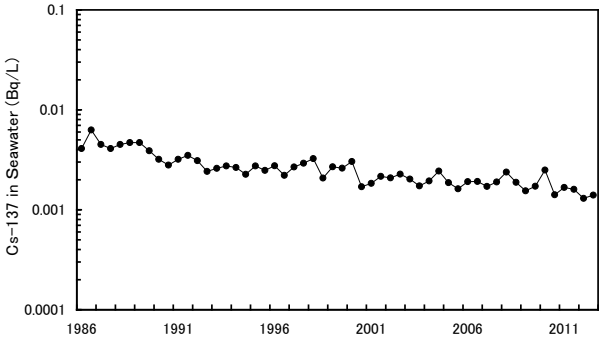

Fig. 5 Variation in concentration of Cs-137 in seawater from 1986 until 2012.

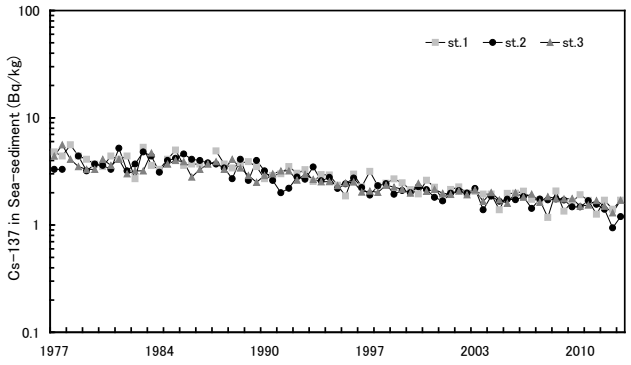

Fig. 6 Variations in concentration of Cs-137 in sea-sediment from 1977 until 2012.

Prefecture, of the FDNPPA was smaller than that from the CNPPA.

(2) Deposited amounts of radioactive cesium

Figure 3 indicates that monthly deposited amounts of Cs-137 in Maizuru and Kyoto began to increase in March 2011, reached the highest level in April, and then returned to the level before the FDNPPA in December. The influence, on Kyoto Prefecture, of the FDNPPA appears to have been about 10% of that from the CNPPA, as indicated by a comparison between the peak height of the monthly deposited amount of Cs-137 caused by the FDNPPA and that caused by the CNPPA. This figure also shows several peaks corresponding to Chinese atmospheric nuclear tests conducted from 1978 to 1980. The deposited amounts of Cs-137 were significantly larger in the early 1960s, during which time the United States and the former Soviet Union repeatedly conducted atmospheric nuclear tests[3].

The sums of monthly deposited amounts of Cs-137 and Cs-134 in Maizuru from March to December, 2011 were 32.7 and 33.7 Bq/m^2, respectively. The ambient dose rate at 1 m above ground level from the contamination by these two radionuclides was found to be 0.25 nSv/h, as a result of calculation with conversion factors[4]. This value is consistent with the fact that no change corresponding to this contamination was observed in the level of the dose rate after the FDNPPA, since the usual variations due to meteorological conditions are significantly larger than the change arising from this contamination.

(3) Radioactive cesium in soil, seawater, sea-sediment, plants, and fish

Figures 4–6 show the variations in the concentration of Cs-137 in surface soil, seawater, and sea-sediment. The cesium-137 concentrations in these three types of samples collected in July or August, 2011 showed downward trends.

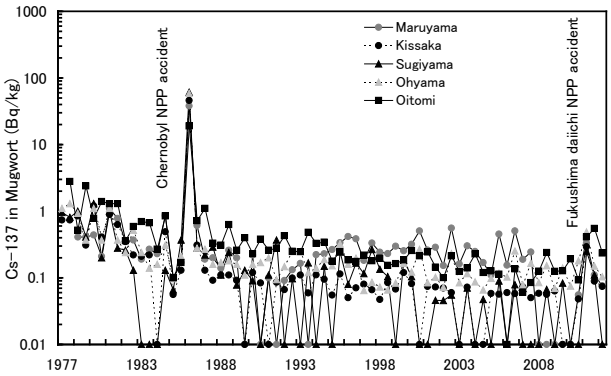

Fig. 7 Variations in concentration of Cs-137 in mugwort from 1977 until 2012.

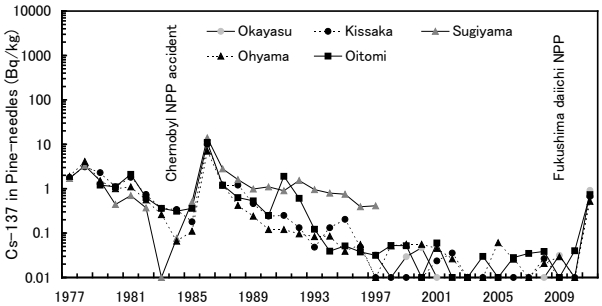

Fig. 8 Variations in concentration of Cs-137 in pine-needles from 1977 until 2011.

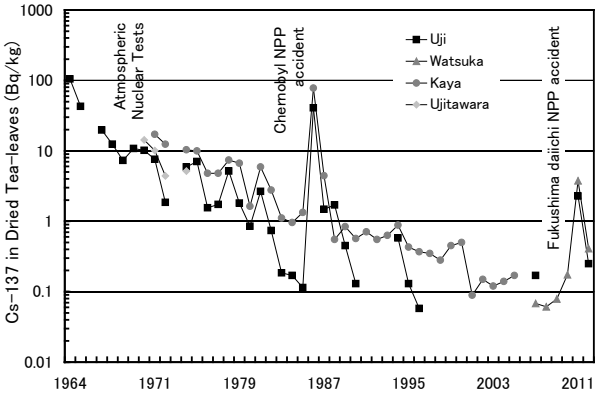

Fig. 9 Variations in concentration of Cs-137 in dried tea-leaves from 1964 until 2012.

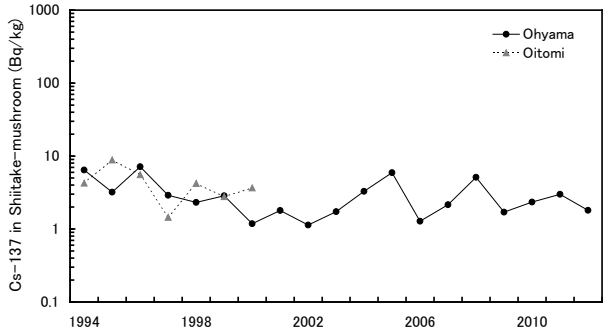

Fig. 10 Variations in concentration of Cs-137 in shiitake-mushrooms from 1994 until 2012.

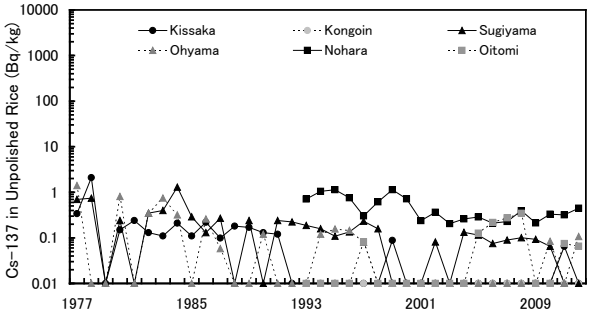

Fig. 11 Variations in concentration of Cs-137 in unpolished rice from 1977 until 2012.

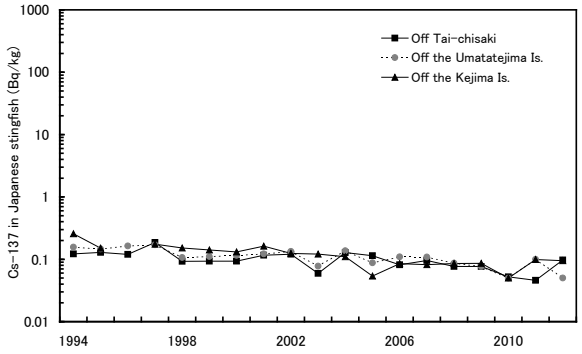

Fig. 12 Variations in concentration of Cs-137 in Japanese stingfish from 1994 until 2012.

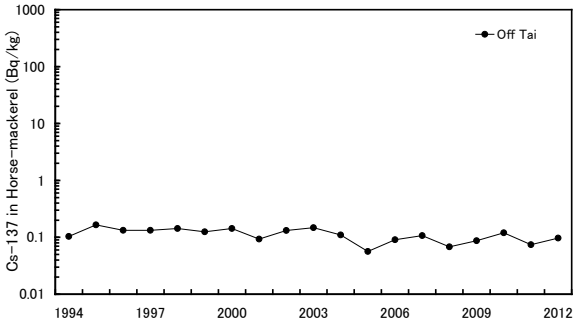

Fig. 13 Variation in concentration of Cs-137 in horse-mackerel from 1994 until 2012.

The surface soil was sampled at seven locations on July 26. Although cesium-137 was detected at every location, cesium-134 was detected only at one location. The concentrations of Cs-137 and Cs-134 at this location were 20 ± 0.51 and 0.90 ± 0.24 Bq/kg, respectively. This result implies that the amount of Cs-137 added by the FDNPPA was significantly less than that accumulated from past atmospheric nuclear tests and the CNPPA, since the deposited amounts of Cs-137 and Cs-134 after the FDNPPA were nearly equal, as described in the preceding paragraph.

The variations in the concentration of Cs-137 in mugwort, pine-needles, and dried tea-leaves are shown in Figs.7–9. These figures indicate increases of the Cs-137

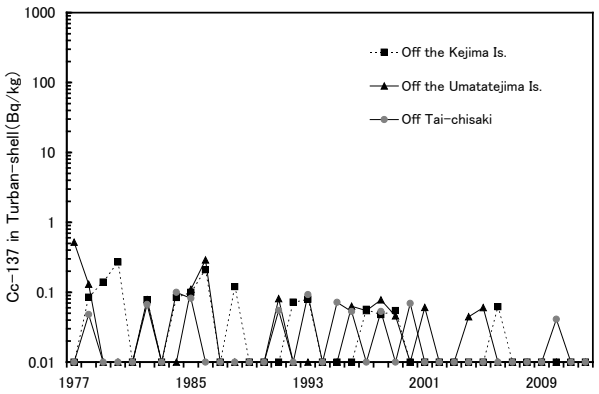

Fig. 14 Variations in concentration of Cs-137 in turban-shell from 1977 until 2012.

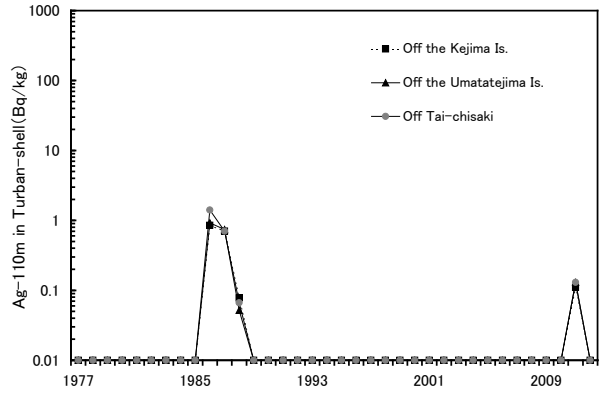

Fig. 15 Variations in concentration of Ag-110m in turban-shell from 1977 until 2012.

concentrations caused by the FDNPPA, but they were less than 10% of those caused by the CNPPA. Figures 10–14 show the variations in the concentration of Cs-137 in shiitake-mushrooms, unpolished rice, Japanese stingfish, horse-mackerel, and turban-shell. The Cs-137 concentrations in these samples showed downward trends, resembling those in surface soil, seawater, and sea-sediment. Mugwort, pine-needles, and tea-leaves showed larger variations in Cs-137 concentration than the other samples, which could probably be ascribed to direct deposition on leaves and foliar uptake of radioactive cesium[5]. For reference, when the concentration of radioactive cesium in dried tea-leaves is below 200 Bq/kg, that in the tea brewed from them generally falls below 10 Bq/kg.

(4) Radioactive silver in turban-shell

It is apparent from Figs.14 and 15 that cesium-137 was not detected in turban-shell collected on 29 June, 2011, although silver-110m was detected then, whereas it had not been detected after the CNPPA. From an annual ingestion of 6.0 g per day of this turban-shell with a concentration of silver-110m of 0.13 Bq/kg, the committed effective dose

would be 8.0×10^{-7} mSv[6]. Notably, silver-110m was not detected in either seawater or sea-sediment, which suggests that shellfish tend to concentrate silver from their environment [7].

4. Conclusions

The level of absorbed dose rate in the air did not change after the FDNPPA. Cesium-137, cesium-134, and iodine-131were detected in certain types of vegetables and fish collected in Kyoto Prefecture after the FDNPPA at concentrations significantly lower than 100 Bq/kg. In addition, silver-110m was detected in turban-shell. The concentrations of these four radionuclides were extremely low, so that the public exposure from their ingestion would be significantly lower than 1 mSv per year. The influence, on Kyoto Prefecture, of the FDNPPA appears to be less than 10% of that from the CNPPA, as indicated by our comparison of the deposited amount of Cs-137 and the concentration of Cs-137 in environmental samples recorded after both events.

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