Survey of radioactive contamination distribution in the Naka-Dori area, Tohoku, Japan

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The Kinki University Atomic Energy Research Institute investigated radioactive contamination due to the Fukushima Daiichi Nuclear Power Plant accident in urban areas of the Fukushima Naka-Dori Area in the TOHOKU region, Japan. A specific activity measurement of the surface soil and a survey of the dose rate distribution in urban areas were performed. From the results of this research, a decrease in dose rate in paved areas became clear, and differences due to the "wash out effect" in paved areas for different paving materials was measured and verified.

Key Words: *dose rate, distribution, specific activities*

1. Introduction

On March 11, 2011, the Tohoku Region Pacific Coast Earthquake and the subsequent tsunami occurred, causing the Fukushima Daiichi Nuclear Power Plant (Fukushima Daiichi NPP) accident. As a result of the failure of the NPP's coolant systems, hydrogen explosions occurred that released radioactive materials to the general environment[1)-6)].

The released radioactive materials were dispersed as radioactive plumes over wide ranges of the TOHOKU and KANTO regions. These radioactive plumes were captured by rain and snow, and subsequently fell to the ground. Several surveys tried to measure the contamination in general environments[1),6)], but detailed information is not yet available.

The Kinki University Atomic Energy Research Institute (Kinki Univ. AERI) conducted research in the Fukushima area from the middle April of 2011[6)]. Two types of measurement were conducted: the measurement of the specific activity of radioactive materials in surface soils; and the measurement of dose rate distributions in urban areas. From these measurements, it was clear that the concentration of radioactive materials that had dispersed from the Fukushima Daiichi NPP decreased faster than the physical half-life of the radioactive materials themselves in the urban parts of the Fukushima Naka-Dori area.

In this paper, the methods used, and some of the results of the measurements are presented.

2. Method

Measurements were taken at three points in the Fukushima Naka-Dori area, TOHOKU region, Japan. The first point was the Arakawa-Undo Park neighborhood, in the Fukushima city of the Fukushima prefecture (37.745º N, 140.461º E); the second point was the Hayama Park neighborhood, in the Koriyama city of the Fukushima prefecture (37.395º N, 140.375º E); and the last point was the Kuroiso Park neighborhood, in the Nasu-Shiobara city of the Tochigi prefecture (36.976º N, 140.053º E). These points are shown in Figure 1.

The methods of the two measurements are described in the following sections.

Figure 1. Location of the research points with respect to the Fukushima Daiichi Nuclear Power Plant.

(1) Measurement of the specific activity in surface soils

Surface soils were collected at each measurement point for every month from April 2011. Soil samples were collected from a 30 × 30 cm^2 area and a ground depth of 1 cm. The collected soils were packed in U-8 sample cases. Soil samples were measured with a high pure germanium detector at Kinki Univ. AERI in Osaka and the measured gamma spectrum was analyzed using the nuclide library of ORTEC EG&G. The measurement time was 1800 seconds for each sample.

(2) Dose rate distribution survey

In this measurement, a GPS-linked NaI(Tl) scintillation counter[7] was used to simultaneously record the dose rates and location. The GPS-linked NaI(Tl) scintillation counter is composed of three components: the first component is the radiation detection unit, which uses a NaI(Tl) survey meter (TCS-171: Hitachi-Aloka Medical Co., Ltd.) and a microcomputer board (CQ-V850: ESP Co., Ltd.); the second component is the GPS receiver unit, which uses a USB-linked GPS receiver (UMGPS/MF: IODATA DEVICE Inc.; GPS receiver chip is SiRF StarIII); and the last component is a data acquisition unit, an Ultra-Mobile PC (FM-V BIBLO LOOX U/ C30: Fujitsu Co., Ltd.). The radiation detection unit and the GPS receiver unit are linked to the data acquisition unit where dose rate and GPS data are saved. The data acquisition software was developed and built using the Visual C#/ .NET Framework (Microsoft).

The whole system was put in a portable bag with the detection head of the radiation detector positioned 50 – 60 cm above ground, and the measurement was taken while walking at a speed of around 100 m/min.

3. Results

(1) Measurement of the specific activity in surface soils

The results of these measurements ranging from April 2011 to July 2012 are already published[6) 8) and 9)]. We show here the results from August 2012 to October 2012. As already published, almost all of the radioactive nuclides from the Fukushima Daiichi NPP decayed to approximately background levels by the middle of 2011, except for ^{134}Cs and ^{137}Cs. Tables 1 and 2 show the specific activities of soil samples collected and measured in August, September and October of 2012 and Figure 2 shows the trends of ratio in ^{137}Cs specific activity for April 17, 2011 samples. The data are in the same decreasing trends as already published and the ratios keep around 0.1 as shown in Figure 2.

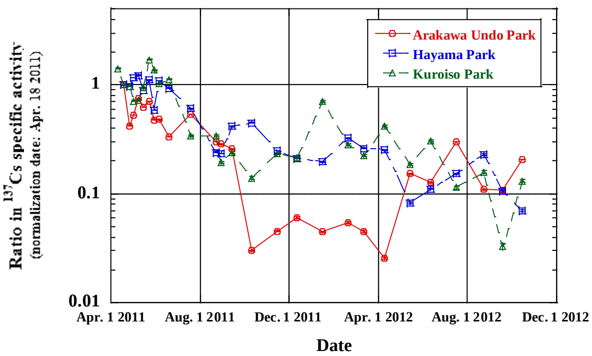

Figure 2. Time dependence of the ratio in ^{137}Cs specific activity of the surface soil samples.

(2) Dose rate distribution survey

Some of the earlier results of this measurement are published in references[6) 8) and 9)], where the dose rate distributions in the urban part of the Fukushima Naka-Dori area had changed. The change in the dose rate in paved areas (with time) is described in this paper.

A characteristic dose rate distribution change is shown in Figure 3. Figures 3 (a) and (b) show the dose rate distributions of the Fukushima station neighborhood close to measurement point 1: Arakawa-Undo Park. Figure 3 (a) shows the dose rate distribution on April 17, 2011, whereas Figure 3 (b) shows the dose rate distribution on October 13, 2012.

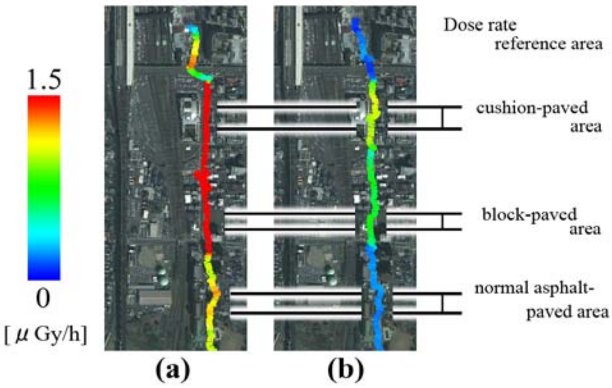

Figure 3. Dose Rate distributions in Fukushima city. Lines indicate the survey route and their color the measured dose rate on (a) April 17, 2011, and (b) October 13, 2012.

The dose rate on October 13, 2012 was lower than that on April 17, 2012 (as shown in Figure 3), and the dose rate distribution became much clearer on October 13, 2012. The higher dose rate areas shown in Figure 3 (b) were where the streets were paved with cushion, the average dose rate areas were where the streets were paved with blocks, and the lower dose rate areas were where the streets were paved with normal asphalt. The dose rates of these 3 places decreased with time; for a more detailed analysis, the average dose rates of reference areas in Figure 3 were compared with the calculated dose rate trends. The averaged dose rates are shown in Figure 4.

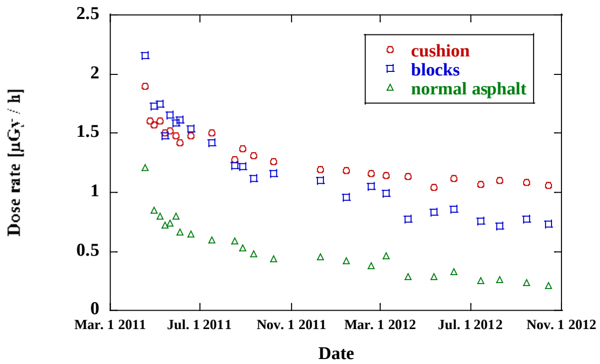

Figure 4. Time dependence of the dose rate for different paving materials.

The calculated dose rate trends were determined as follows. First, the time dependence of the radioactive nuclides ratio in a given area was calculated from the specific activity of the appropriate April 17, 2011 sample and the physical half-lives of the detected nuclides. Next, the relative dose rate by radioactive materials derived from the Fukushima Daiichi NPP was calculated from the sum of the product of the nuclide ratio and the air kerma-rate constant. Lastly, the dose rate trends were calculated using an environmental back-ground dose rate (published by Abe in 1981[10]), and the relative dose rate trends (which were normalized with respect to the measured dose rates). In this analysis, the normalization date was April 29, 2011.

The ratios of the deviations between the measured and calculated dose rates (for the calculated net dose rates) are shown in Figure 5. Note that the trends of the ratios are different with respect to one another. The decrease in gradient of the cushion-paved area was smallest, and the gradient of normal asphalt-paved area was largest of the 3 areas, as shown in Figure 5. If this ratio can be considered as a measure of the physical half-life of the radioactive material, then the decrease of this ratio means that the radioactive materials have moved out of this place. The decrease in the gradients of the ratio shows the differences of the “wash out effect” between different paved materials.

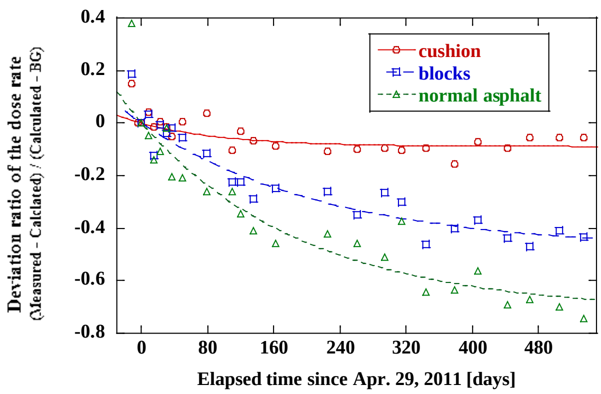

Figure 5. Ratio of the deviations between measured and calculated dose rates for different paving materials.

4. Conclusion

Kinki Univ. AERI conducted two studies on the radioactive contamination derived from the Fukushima Daiichi NPP in urban parts of the Fukushima Naka-Dori area starting in April 2011. One of these measurements was of the specific activities of surface soils, and the other was a survey of the dose rate distributions. The results presented herein demonstrate that the dose rate distribution changed with time and that the dose rate distributions in paved areas have different characteristics. In Fukushima city, the change in dose rate in paved areas was linked to the type of paved material, where a difference in the decreasing gradient indicated the impact of different “wash out effects”.

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Table 1. ^{134}Cs specific activities of surface soil samples.

Collected date (Measured date)	Arakawa Undo Park [kBq/kg]	Hayama Park [kBq/kg]	Kuroiso Park [kBq/kg]
Aug. 10, 2012 (Aug. 24, 2012)	3.81 ± 0.05	3.07 ± 0.04	0.51 ± 0.02
Sep. 15, 2012 (Sep. 18, 2012)	3.59 ± 0.05	1.46 ± 0.03	0.11 ± 0.01
Oct. 14, 2012 (Oct. 15, 2012)	6.72 ± 0.06	0.90 ± 0.02	0.38 ± 0.02

Table 2. ^{137}Cs specific activities of surface soil samples

Collected date (Measured date)	Arakawa Undo Park [kBq/kg]	Hayama Park [kBq/kg]	Kuroiso Park [kBq/kg]
Aug. 10, 2012 (Aug. 24, 2012)	6.06 ± 0.07	5.12 ± 0.06	0.81 ± 0.02
Sep. 15, 2012 (Sep. 18, 2012)	5.96 ± 0.07	2.38 ± 0.04	0.17 ± 0.01
Oct. 14, 2012 (Oct. 15, 2012)	11.3 ± 0.08	1.56 ± 0.03	0.67 ± 0.02