Rapid Communication

Survey of Living Environmental Land Contaminated with Radioactive Materials due to Fukushima Daiichi Nuclear Plant Accident

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Radioactive materials were released to the general environment due to the accident at the Fukushima Daiichi Nuclear Power Plant. The released radioactive materials fell and contaminated the land mainly in the Tohoku and Kanto areas of Japan. We surveyed the air dose rates in relation to the pave condition of the land, and investigated the contamination level in some nonpaved areas at the center of Fukushima City, Koriyama City, and Nasushiobara City. From the survey results, the dose rates of the nonpaved areas were found to be higher than those of the paved areas, and the dose rates of the paved areas depend on the paving materials of the area. The contamination level of the nonpaved area in Nasushiobara City was below the regulation level of specific activities in a radiation-controlled area in Japan. However, the contamination levels in the nonpaved areas in Fukushima City and Koriyama City were above the regulation level.

KEYWORDS: Fukushima Daiichi, contamination level, living environment, dose rate, pave condition

I. Introduction

As a result of the magnitude 9.0 earthquake off the Pacific Coast of Tohoku on March 11, 2011 and the subsequent tsunami, the residual heat removal system (RHRS) of the Fukushima Daiichi Nuclear Plant (hereinafter referred to as "1F") owned by Tokyo Electric Power Co., Inc. experienced functional failure [1)]. This failure resulted in the destruction of the building of Unit 1 of 1F by an explosion at 15:36 on March 12th, 2011 [2)] and the building of Unit 3 was also destroyed by another explosion at 11:01 on March 14th [3)]. The building of Unit 4 was also damaged by a fire [4)], and Unit 2 experienced damage to its suppression chamber as well, due to the explosion [5)]. The series of explosions and damage to the buildings released a significant amount of radioactive material into the general environment, and the soils of the Fukushima Prefecture and the Tohoku and Kanto areas became contaminated.

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An increased air dose rate caused by this radioactive contamination was immediately observed in various locations [6], and since the incident, the air dose rate has been continuously monitored and opened for public. Furthermore, the density of the radioactive material contained in agricultural soils around Fukushima Prefecture was measured to monitor the potential influence on agricultural crops [7, 8]. The monitoring/measurements were conducted by local governments in various regions, and action directives for the residents were issued based on the observed radiation values.

However, the dynamic status of radioactive materials in the environment is not uniform because it depends significantly on peripheral factors. The environmental radiation dose rate investigation revealed the existence of places where air dose rates were higher than in the surrounding areas [9-12]. Therefore, a portable radiation position measurement system was used to follow the activity in locations with higher dose rates [13], and an exploration of high dose rate spots in the dynamic environment was conducted. Furthermore, in spots where a significantly higher dose rate was observed than in the surroundings, the soil was sampled, and radionuclide analyses were conducted. In this paper, the results of the air dose rate measurements and soil nuclide analyses are reported.

II. Measurement Methodology and Locations

A simplified radioactivity position measuring system consisting of a NaI (Tl) survey meter (Aloka: TCS-171) and a GPS receiver [13] was used. The air dose rate was measured once per second, and the results were displayed on a map for further analyses.

The survey meter probe was installed 50–60 cm above ground level, and the air dose rate was measured while moving at a walking speed of approximately 100 m/min. Measurements were made on April 16th and 17th, 2011 at three locations: Kuroiso Park, Nasushiobara City, Tochigi Prefecture (100 km southwest of 1F, at approx. 36.976° N and 140.053° E), Hayama Park, Koriyama City, Fukushima Prefecture (60 km west of 1F, at approx. 37.395° N and 140.375° E), and Arakawa Athletic Park, Fukushima City, Fukushima Prefecture (60 km northwest of 1F at approx. 37.745° N and 140.461° E). The approximate size of the surveyed areas was respectively 100 m × 300 m, 130 m × 300 m and 160 m × 750 m. The amount of precipitation per unit area for each location was considered to be equal because the survey areas were not large. Additionally, the weather during the measurements was clear at all locations.

Where the dose rate was significantly higher than in the surroundings, the top 1 cm of surface soil was sampled from an area of 30 × 30 cm and sealed in a U-8 container at the site. The surface of the container was cleaned at the site and again at Kinki University and double-sealed with vinyl bags. The mass of the sampled soil was 160.9 g at Kuroiso Park, Nasushiobara, Tochigi Prefecture, 174.7 g at Hayama Park, Koriyama City, Fukushima Prefecture, and 149.5 g at Arakawa Athletic Park, Fukushima City, Fukushima Prefecture. The γ-ray spectra of the prepared soil samples were measured using a high-purity Ge detector at the Kinki University Atomic Energy Research Institute on April 18th, 2011, and a nuclide analysis was performed using the nuclide library of SEIKO EG&G.

III. Results and Discussion

Measurements of air dose rates were classified by land surface conditions and observed for

1 min (60 data points) with no significant fluctuation, and the maximum, minimum, and average air dose rates were obtained. The air dose rates are shown in **Figures 1–3**, where the plotted points are the average and the bars on the plotted points indicate the maximum and minimum of the 60 data points. Figure 1 shows the measurements taken at Kuroiso Park, Nasushiobara City, Tochigi Prefecture, Figure 2 shows the data from Hayama Park, Koriyama City, Fukushima Prefecture, and Figure 3 displays the data from Arakawa Athletic Park, Fukushima City, Fukushima Prefecture. The results show the trend of higher air dose rates above non-paved land surfaces and lower rates above paved areas.

Comparison of the air dose rates over soil and asphalt land surfaces shows that the soil locations exhibited approximately 1.4-fold higher values in the Kuroiso Park neighborhood,

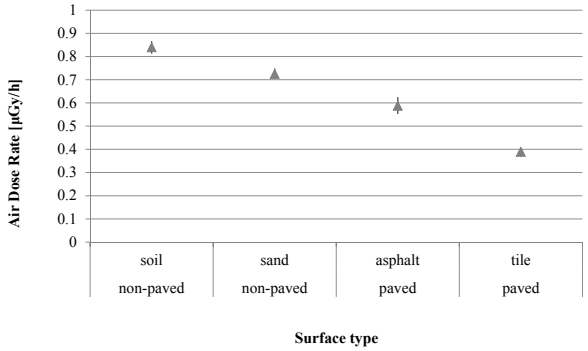

Figure 1 Air dose rate in the Kuroiso Park neighborhood, Nasushiobara City

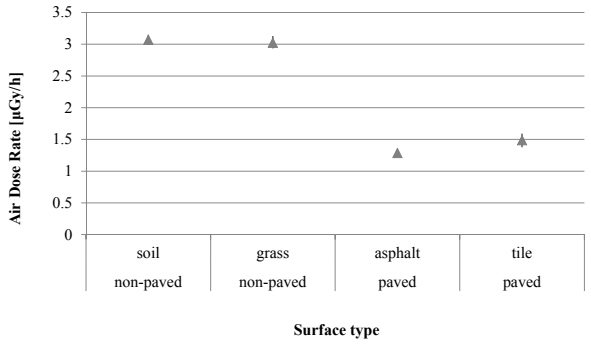

Figure 2 Air dose rate in the Hayama Park neighborhood, Koriyama City

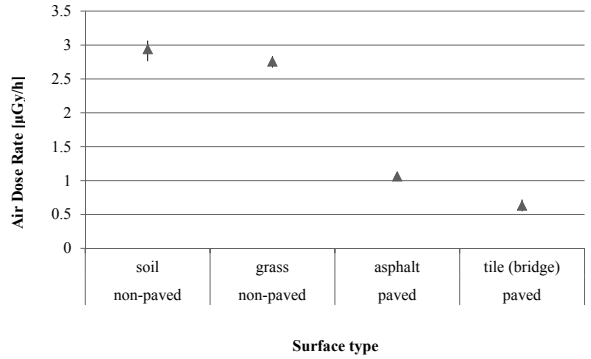

Figure 3 Air dose rate in the Arakawa Athletic Park neighborhood, Fukushima City

Table 1 Specific activity of soil samples

Nuclide	Half–life [day]	Nasushiobara city Kuroiso park [Bq/kg]	Koriyama city Hayama park [Bq/kg]	Fukushima city Arakawa Athletic Park [Bq/kg]	Regulation level* [Bq/kg]
^{95}Nb	35	2.87E1 ± 0.80E1	7.21E1 ± 0.02E1	1.12E2 ± 0.25E2	1.0E4
^{131}I	8	5.48E2 ± 0.16E2	3.51E3 ± 0.04E3	1.90E4 ± 0.01E4	1.0E5
^{129}Te	0.048	1.98E3 ± 0.18E3	5.74E3 ± 0.35E3	2.04E4 ± 0.06E4	1.0E5
^{129m}Te	34	2.68E3 ± 0.28E3	9.11E3 ± 0.56E3	3.26E4 ± 0.10E4	1.0E6
^{132}Te	3	2.44E1 ± 0.75E1	8.65E1 ± 1.54E1	2.29E2 ± 0.29E2	1.0E5
^{134}Cs	753	3.98E3 ± 0.04E3	1.71E4 ± 0.01E4	4.33E4 ± 0.01E4	1.0E4
^{136}Cs	13	1.54E2 ± 0.10E2	6.07E2 ± 0.19E2	1.61E3 ± 0.04E3	1.0E4
^{137}Cs	11020	4.46E3 ± 0.04E3	1.92E4 ± 0.01E4	4.89E4 ± 0.01E4	1.0E4

* minimum specific activity that defines a radiation area to be controlled under Japanese regulations[14)]

2.4-fold higher values at Hayama Park, and 2.8-fold higher values at Arakawa Athletic Park. This clearly shows a trend of higher levels of residual radioactive material at non-paved locations compared to the levels at paved locations.

Table 1 shows the nuclide analyses of the sampled soils. Radioactive materials, including ^{137}Cs and ^{131}I considered to have been released from 1F, were detected in all soil samples. Comparison of the detected radioactive material concentration with the specific isotope concentration (hereinafter referred to as the "lower limit concentration") [14)] that releases the amount of radioactivity stipulated in Article 1 of the "Order for Enforcement of Act on Prevention of Radiation Disease Due to Radioactive Isotopes, etc". shows that the concentrations were below the lower limits for the detected nuclides at Kuroiso Park, Nasushiobara City, Tochigi Prefecture. However, the samples from Hayama Park, Koriyama City, Fukushima Prefecture and Arakawa Athletic Park, Fukushima City, Fukushima Prefecture showed concentrations above the lower limit for ^{134}Cs and ^{137}Cs.

These measurements were conducted approximately 1 month after the release of a large amount of radioactive material from 1F, and the nonuniform pattern in the detected residual radioactive materials is considered to be the result of the precipitation amount of the radioactive materials, the dynamic status of the local conditions and soil properties, the deposition process of radioactive materials, and the wider distribution or outflow of radioactive materials due to rainfall, strong winds, and other environmental processes. The contribution of these processes to the dynamic status of the observed radioactive materials in the environment will be the subject of a future study.

IV. Conclusions

A trend of higher air dose rates in non-paved areas compared to those observed in paved areas was observed approximately one month following contamination by radioactive materials. Furthermore, the nuclide analyses of soil specimens from the non-paved areas where contamination occurred showed that soil contamination exceeding the lower limit occurred in the non-paved locations in residential districts in Fukushima and Koriyama Cities as of April 17th, 2011.

The places where we conducted the measurements were 60–100 km away from 1F, where soil contamination due to the accident was comparatively minor. However, a difference in air dose rate based on the land surface pavement status was observed. The data quantifying the difference in air dose rates associated with land surface pavement status will be helpful for future efforts to reduce air and exposure dose rates.

Because this event is ongoing, we will continue to monitor the air dose rate, sample relevant soils, and perform nuclide analyses.

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