ENVIRONMENTAL RADIATION AT IZU-OSHIMA ISLAND AFTER THE FUKUSHIMA DAIICHI NUCLEAR POWER PLANT ACCIDENT

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Environmental radiation at Izu-Oshima Island was observed six months after the accident at the Fukushima Daiichi Nuclear Power Plant (F1-NPP). A car-borne survey of the dose rate in air was conducted over the entire island and the results were compared with measurements performed in 2005 (i.e., before the accident). The activity concentrations of cesium-134 and cesium-137 were also measured using a germanium detector. The dose rate in air was found to be 2.9 ± 1.2 times higher than that in 2005 and cesium-134 was detected on Izu-Oshima Island. These results are attributed to the accident at the F1-NPP.

INTRODUCTION

A magnitude 9.0 earthquake occurred off the coast of eastern Japan (38. 32° N, 142. 37° E) at 14:46 JST on March 11, 2011, triggering a devastating tsunami. It was one of the five most powerful earthquakes recorded in the world since 1900. The tsunami caused a serious accident at the Fukushima Daiichi Nuclear Power Plant (F1-NPP), which was declared to be level 7, the highest level on the International Nuclear Event Scale. It resulted in the release of the artificial radionuclides iodine-131, cesium-134, cesium-137 and others from the F-1 NPP [(1)]. These radionuclides were detected not only in Japan, but also in Europe and the American continent [(2–4)]. Cesium contamination is currently a serious problem in some regions of Japan [(5)].

Our group has continually monitored environmental radiation on Izu-Oshima Island (34. 44° N, 139. 23° E) from 2005. Izu-Oshima Island is a volcanic island in the Izu archipelago. It is located about 350 km southwest of the F-1 NPP (37. 42° N, 141. 04° E). The survey was continued after the accident at the F-1 NPP as a part of regional surveillance of the F-1 NPP accident. These continuous observations are important for analyzing the effect of the F-1 NPP accident.

In this study, the status of contamination by the artificial radionuclides cesium-134 and cesium-137 at Izu-Oshima Island was observed six months after the F-1 NPP accident and compared with environmental radiation levels. The effect of the accident on the environment was estimated.

MATERIALS AND METHODS

Dose rate measurements in air were performed and the concentrations of cesium radionuclides were measured on August 10 and 11, 2011 at Izu-Oshima (Figure 1).

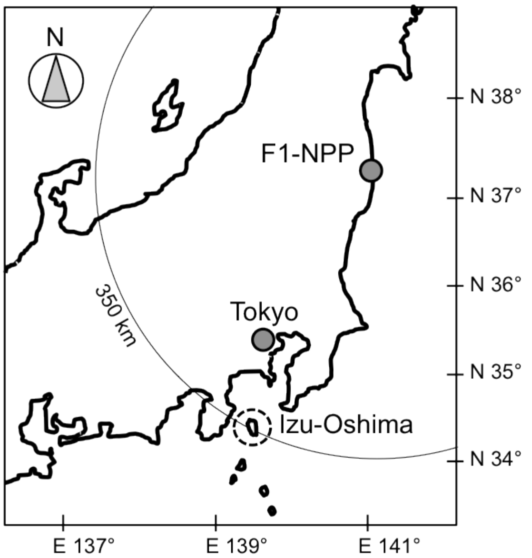

Figure 1 Positions of the F-1 NPP and Izu-Oshima Island. Izu-Oshima Island is located 350 km southwest of the F-1 NPP.

Dose rate measurements in air

The dose rates in air (nGy h^{-1}) were measured along the shoreline of Izu-Oshima Island on August 11 (Figure 2). A car-borne survey was conducted using a 2″×2″ NaI(Tl) scintillation spectrometer (Osprey, Canberra Industries, Inc., USA). Latitude and longitude at each measurement point were measured with global positioning system at the same time as the survey measurements were made. This method is commonly used to rapidly assess dose rates over an extended area in emergencies [5]. Measurements were performed every minute. The shielding effect of the car body was estimated by measuring the count rates for 10 minute inside and outside the car at five locations on the island. A preliminary experiment was performed to determine the correlation between the count rates measured inside and outside the car and a good correlation ($R^2 = 0.996$) was obtained (Figure 3). The following linear approximation equation was used to estimate the count rates in air outside the car (N_{out})

$$N_{out} = 1.44 \times N_{in} + 0.94 \qquad (1)$$

where N_{in} (cps) is the count rate inside the car. The correlation between the count rate and the dose rate (nGy h^{-1}) obtained for the scintillation spectrometer was evaluated. The measurement was performed for 10 minute at six locations on the island and a good correlation was obtained ($R^2 = 0.988$; Figure 4). Based on these preliminary experimental results, the dose rates in air (D_{air}: nGy h^{-1}) were calculated using

$$D_{air} = 0.29 \times N_{out} \qquad (2).$$

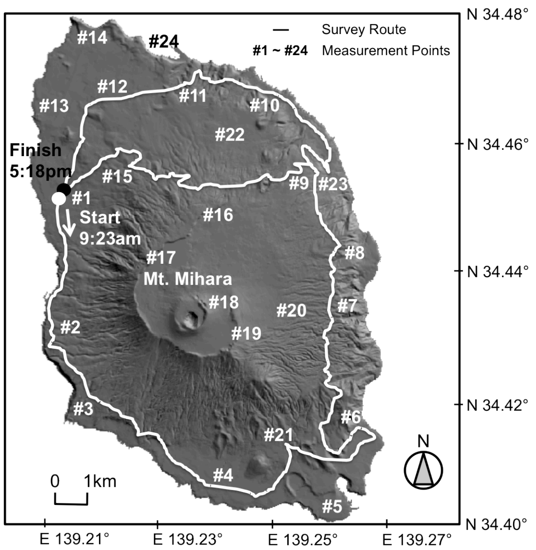

Figure 2 Survey route for measuring the dose rates in air using a NaI(Tl) scintillation spectrometer.

All the obtained data from the car-borne survey were plotted on a distribution map and the mean dose rates (nGy h^{-1}) were calculated. These data were then compared with data obtained in 2005. The mean annual effective dose (mSv y^{-1}) was also calculated. A dose coefficient of 0.7 Sv/Gy was used for adults in this study [6]. In addition, data obtained at 7 locations (Figure 2: #1 – #3, #10, #11, #15, #23) in 2011 and 2005 were compared in order to reduce the effect of variations in the environmental radiation from point to point.

A fixed-point observation technique was also employed to measure dose rates in air. They were measured with a CsI(Tl) scintillation survey meter (PDR-101, Aloka Co., Japan) at 23 locations (Figure 2: #1 – #23). A pocket survey meter was positioned 0 and 1 m above the ground surface. Measurements were recorded over consecutive 30 sec intervals during a total recording period of 5 minute.

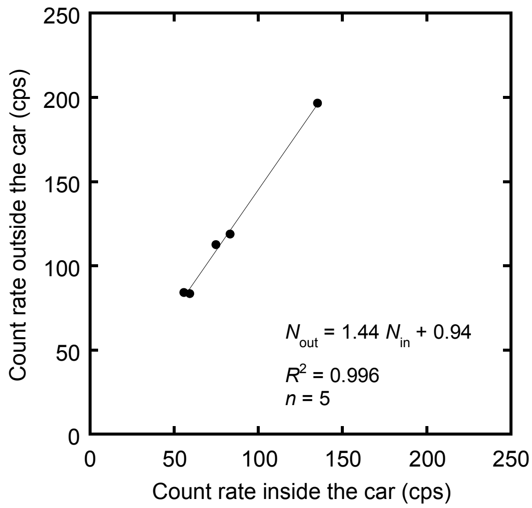

Figure 3 Correlation between count rates inside and outside the car.

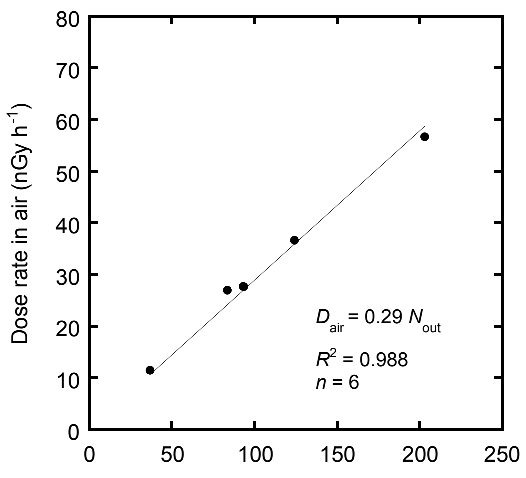

Figure 4 Correlation between count rates outside the car and dose rate in air.

Radioactivity concentration measurements

A high-purity germanium semiconductor detector (GMX10P, Ortec, USA) was used to evaluate the radioactivity concentrations (Bq kg^{-1}) of cesium-134 and cesium-137 at 21 points (Figure 2: #1 – #21). Soil samples were collected from 2 cm below the surface at each point on August 10, 2011. The soil samples were sieved and <2 mm particles were retained for this measurement. Sand samples were also collected from the ocean floor at a depth of 1.5 m on August 10 (Figure 2: #24). These samples were placed in cylindrical polypropylene containers (48 mmϕ × 55 mm). The measurement time for each sample was 3,600 s. The cesium-134 and -137 concentrations were estimated from the peak areas (0.605 and 0.796 MeV for cesium-134 and 0.662 MeV for cesium-137), the peak detection efficiency, the gamma-radiation yield, and the mass of the sample.

RESULTS

Dose rate measurement in air

Figure 5 shows a distribution map of the dose rates measured in air by a car-borne survey on Izu-Oshima Island in 2011 (n = 73). It should be noted that, using the same gradation scale, a similar map constructed with data measured in 2005 (n = 137) indicated a uniform distribution (i.e., ~ 20 nGy h^{-1}).

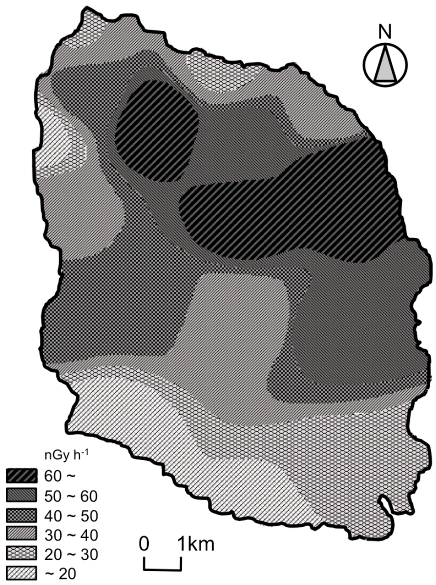

Figure 5 Distribution map of the dose rate in air of Izu-Oshima Island after the F-1 NPP accident.

Higher dose rates in air were detected in the north and northeast areas of Izu-Oshima Island compared to those measured in 2005. The arithmetic mean dose rates in air in 2011 and 2005 were 37 ± 12 and 13 ± 3 nGy h^{-1}, respectively; thus, the rate in 2011 is 2.9 ± 1.2 times higher than that in 2005. The ranges of dose rates in air were 18 - 63 nGy h^{-1} and 7 - 21 nGy h^{-1} in 2011 and 2005, respectively. If the indoor and outdoor dose rates in air were assumed to be equal, then the projected annual effective dose (mSv y^{-1}) was calculated to be 0.23 mSv in 2011 as compared to 0.08 mSv in 2005. The dose rates in air obtained from the same places (n = 7) in 2011 and 2005 were also compared; they were 2.9 times higher in 2011 than in 2005. The dose rates in air (n = 23) at 0 and 1 m above the ground, obtained by the fixed-point observation technique, were 42 ± 20 and 34 ± 14 nGy h^{-1}, respectively.

Radioactivity concentration measurements

The radioactivity concentrations of cesium-134 and -137 in soils (n = 21) and sands (n = 3) were measured using a high-purity germanium semiconductor detector. The ranges of radioactivity concentrations in soils (n = 21) were 6.4 - 394.6 Bq kg^{-1} for cesium-134 and 7.6 - 499.3 Bq kg^{-1} for cesium-137. For sands (n = 3), the ranges were 0.8 - 3.0 Bq kg^{-1} for cesium-134 and 2.8 - 4.3 Bq kg^{-1} for cesium-137. In contrast, no cesium-134 was detected from either soils or sands in 2005 (i.e., before the accident at the F-1 NPP).

DISCUSSION

The environmental radiation at Izu-Oshima Island was observed six months after the F-1 NPP accident. The measured dose rates in air (Figure 5) in the north and northeast areas of Izu-Oshima Island were higher than those measured in 2005. These areas correspond to woodland with moderate precipitation levels. In addition, a northeast wind blows over Izu-Oshima Island during spring and summer. Since the F-1 NPP is located to the northeast of Izu-Oshima Island (Figure 1), radionuclides associated with the fallout may have adhered to such woodlands. In contrast, the dose rates in air in southern areas of Izu-Oshima Island that is desert region were the same as those measured in 2005. This may be the effect of Mount Mihara (758 m), which is located at the center of the island (Figure 2), and difference of the circumstance in southern regions. Thus, this area might not have been affected by radionuclides emitted by the F-1 NPP.

To estimate the environmental health hazard of this fallout, the annual effective dose (mSv y^{-1}) was calculated to be 0.23 mSv, as mentioned above. However, since islanders do not spend their entire day outdoors, the shielding factor of building and occupancy factor must be considered, which would lead to a lower annual effective dose. In addition, this calculated effective dose was lower than the average annual effective dose in Japan (0.33 mSv y^{-1}) [7] before the F-1 NPP accident. Thus, although the dose rate in air at Izu-Oshima increased by a factor of 2.9 ± 1.2 times after the accident, it does not represent a health hazard. The dose rate in air at the ground was 1.2 ± 0.4 times higher than that at 1 m above the ground. This may be the effect of radionuclide deposited on the ground surface.

Cesium-134 is an artificial radioactive nuclide. It was detected over the whole of Izu-Oshima Island after the F-1 NPP accident. NPP regulations in Japan stipulate that the maximum permissible level of cesium in waste is 100 Bq kg^{-1} [8]. In addition, the designated criterion for safely processing waste by the usual method has been set to 8,000 Bq kg^{-1} by the Ministry of the Environment. The radioactivity concentrations measured in soils in this study satisfy these criteria. In addition, no cesium-134 was detected in 2005. Thus, the presence of cesium-134 in 2011 is clearly an effect of the F-1 NPP accident. However, the data indicates that the levels are well below safety margins. We thus conclude that the F-1 NNP accident has not created a serious health hazard at Izu-Oshima Island.

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