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Note

Survey of Radioactive Contamination along Mt. Fuji's Climbing Routes Following TEPCO's Fukushima Daiichi Nuclear Power Plant Accident

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TEPCO's Fukushima Daiichi Nuclear Power Plant (FDNPP) accident occurred in March 2011, and the resulting release of radioactive nuclides contaminated Mt. Fuji's ground surface. It was of great concern that climbers would be at a risk of being exposed to elevated radiation levels at Mt. Fuji. In this study, dose rates in air (absorbed dose rates in air) were continuously measured while climbing along two popular climbing routes: the Yosida (Kawaguchiko) and Subashiri routes. The dose rates ranged from 15 to 24 nGy/h, which are less than the background level for terrestrial gamma rays in Japan (51 nGy/h). This study suggests that the deposition of artificial radioactive nuclides over the Mt. Fuji and its climbing routes has little effect on the increase of the dose rates in air.

Key words: Dose rate, Fukushima nuclear accident, Manborne survey, Mt. Fuji

1. Introduction

Annually, around 300,000 people climb Mt. Fuji, which is a registered United Nations Educational, Scientific and Cultural Organization World Heritage Site[1)]. These climbers are exposed to ionizing radiation that naturally exists along its tails. The main sources of exposure are cosmic rays from outer space and the Sun, and terrestrial radionuclides in the ground surface[2)]. The exposure to cosmic rays increases with altitude[3)], whereas the exposure to radiation from the ground-surface radionuclides depends on radionuclide content at given locations. When a change in the radionuclide content at a specific location is suspected, it is important to investigate the exposure to the ground-surface radionuclides.

TEPCO's Fukushima Daiichi Nuclear Power Plant (FDNPP) accident occurred in March 2011, and released large amounts of radioactive nuclides[4)]. In order to investigate the extent of contamination by these nuclides along Mt. Fuji's climbing routes, we carried out a series of stationary and continuous measurements. 1) We made stationary measurements of the ambient dose rates using an NaI(Tl) survey meter and of the gamma-ray pulse height distributions at specific locations using an NaI(Tl) spectrometer. 2) We performed continuous measurements of the gamma-ray pulse height distribution along the climbing routes with the NaI(Tl) spectrometer. The results of the stationary measurements of the ambient dose rates and the gamma-ray pulse height distributions at specific locations were reported previously[5)]. Results from these stationary measurements indicated that

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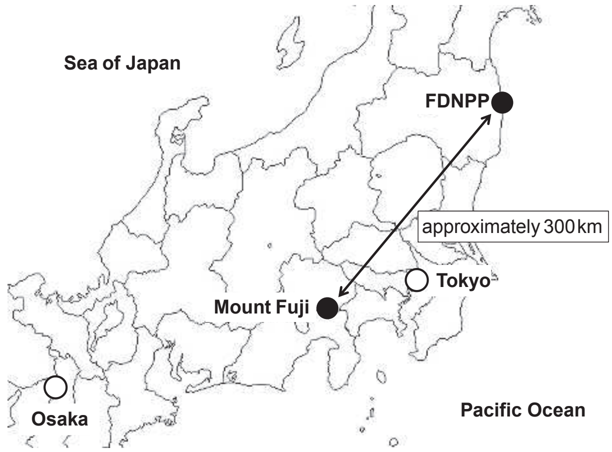

Fig. 1. Locations of the FDNPP and Mt. Fuji.

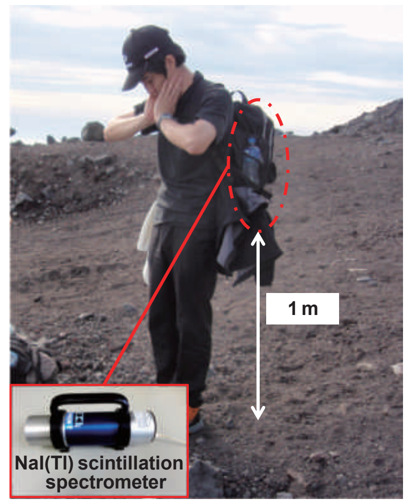

Fig. 2. Photo of the measurements being conducted.

these nuclides had reached Mt. Fuji, which is relatively distant (approximately 300 km southwest) from the FDNPP (Figure 1). In addition, we determined the radiation levels along Mt. Fuji's climbing routes to be at nominal background levels[5]. Conversely, an evaluation of safety from radiation exposure when climbing Mt. Fuji cannot be considered to be complete on the basis of the stationary measurement results alone because some high contamination areas (hot spots) may exist along Mt. Fuji's climbing routes. Thus, continuous measurement data along Mt. Fuji's climbing routes are essential to appropriately evaluate the radiation levels along the climbing routes to further relieve the concerns of the climbers. This study reports the dose rates in air (absorbed dose rates in air) obtained from continuously measured gamma-ray pulse height distributions along two climbing routes.

2. Materials and Methods

2.1. Climbing routes

Measurements were taken along two popular climbing routes: Yosida (Kawaguchiko) and Subashiri. First, we climbed to the top (3720 m) along the Yoshida route from the fifth station on the route. Thereafter, we descended along the Subashiri route to the fifth station on that route. The fifth, sixth, seventh, eighth, and ninth stations along the Yoshida route are at elevations of approximately 2300, 2400, 2700, 3040, and 3600 m, respectively. The fifth, sixth, seventh, eighth, and ninth stations along the Subashiri route are at elevations of approximately 2000, 2600, 2900, 3300, and 3600 m, respectively[6]. The measurements were taken during the daytime on July 9, 2011, prior to the beginning of the most popular annual climbing period.

2.2. Dose rates in air

A 3′ (diameter) × 3′ (thickness) NaI(Tl) scintillation spectrometer (EMF211, EMF, Japan) was used to measure the gamma-ray pulse height distribution within the energy band for terrestrial gamma rays, 1 m above the ground at right angles to the horizon (Figure 2). A GPS recorder (eTrex Vista C, Garmin, Switzerland) was used to obtain the latitude, longitude, and altitude. The gamma-ray pulse height distribution and GPS data were measured throughout the climb at 1-min intervals. The GPS recorder was unable to continuously receive signals due to the presence of trees and the complex route geomorphology. Therefore, gamma-ray spectra were recorded only when GPS signals were received. The dose rates in air under the energy band for terrestrial gamma rays were obtained using the response matrix for environmental gamma-ray spectra unfolding[7, 8]. These rates may have large uncertainties due to the short measurement period (1 min); thus, the dose rates in air were corrected using a conversion factor between the total count rate and dose rate in air (0.0023 nGy/h per cpm), which is the ratio of dose rates in air to count rates at 10 min intervals. The dose rates in air were further corrected by multiplying with 1.2, a factor converting the dose rate measured on the back of a measurer to the dose rate in air without the effects of a human body.

3. Results and Discussion

The dose rates in air with a climbing map are shown in Figure 3. The measured rates from the fifth to sixth stations, the sixth to seventh stations, the seventh to eighth stations, the eighth to ninth stations, and the ninth to top stations along Yoshida route ranged from 17 to 24, 17 to 22, 15 to 21, 17 to 24, and 19 to 22 nGy/h, respectively. Those along Subashiri route ranged from 19 to 24, 19 to 20, 19 to 21, 20 to 22, and 20 to 22 nGy/h, respectively.

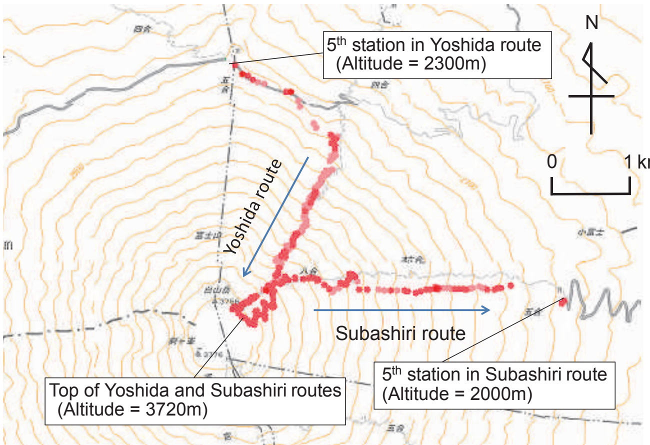

Fig. 3. Map showing the survey results of the dose rates in air measured with the NaI(Tl) scintillation spectrometer. The map is adapted from the "GSI Map for the pale tone" by the Geospatial Information Authority of Japan.
● : < 17 nGy/h; ● : 17 nGy/h ≤ , < 20 nGy/h; ● : 20 nGy/h ≤ , < 23 nGy/h; ● : 23 nGy/h ≤ .

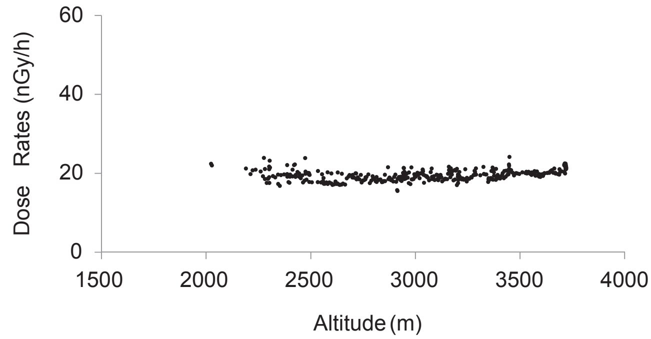

Fig. 4. Variation of dose rates in air measured with the NaI(Tl) scintillation spectrometer with altitude.

No significant difference between the dose rates in air in the Yoshida and Subashiri routes was observed. The ambient dose rates in the affected area around Mt. Fuji (Shizuoka-Shi and Odawara-Shi) have been reported by Oyama[9], and the dose rates in air obtained from these ambient dose rates, with the assumption that Sv is equivalent to Gy, ranged from 60 to 80 nGy/h. The measured dose rates in this study were less than those in the affected area around Mt. Fuji and less than those of the background level for terrestrial gamma rays in Japan (51 nGy/h)[10]. Moreover, the dose rates in this study were also less than those within the energy band for cosmic rays, which are estimated to range from 62 at the fifth station to 100 nGy/h at the top station, on the basis of a formula reported by Furukawa *et al*[3].

The variation of the dose rates in air with respect to altitude is shown in Figure 4. In our previous paper, with respect to stationary measurements[5], we reported that the peak counts of cesium-137 and cesium-134 for the gamma-ray pulse height distributions were lower with increased altitude and we could not confirm the presence of those peaks when the altitude more than 2500 m. These results indicate that the state of contamination on Mt. Fuji's climbing routes was related to altitude. On the other hand, no relationship between the measured dose rate in air in this study and altitude was observed along Mt. Fuji's climbing routes. Holocene non-alkaline mafic volcanic rocks are widely distributed all over Mt. Fuji[11]; i.e., the dose rates in air at Mt. Fuji can be considered almost constant without the contamination due to artificial radioactive nuclides, regardless of the altitude. According to the abovementioned geological perspective, the results in this study suggest that the deposition of artificial radioactive nuclides over the Mt. Fuji and its climbing routes has little effect on the increase of the dose rates in air.

4. Conclusion

The dose rates in air were continuously measured along Mt. Fuji's climbing routes four months after the FDNPP accident. The measured rates were almost constant regardless of altitude and ranged from 15 to 24 nGy/h, which is less than the background level for terrestrial gamma rays in Japan (51 nGy/h). The deposition of artificial radioactive nuclides over Mt. Fuji and its climbing routes has had little effect on increasing the dose rates in air. Environmental radiological surveys, such as the one in this study, should be continued in the future to relieve public concerns about radiation exposure.

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