Continuous Measurement of Environmental Gamma Radiation in Tokyo Using Ge Semiconductor Detector

T. Ichiji and T. Hattori
Central Research Institute of Electric Power Industry
2-11-1 Iwado-kita, Komae-shi, Tokyo 201-8511 Japan.

INTRODUCTION

Radon and its progeny are natural radioactive nuclides and exist in various places on the earth. Some of the radon progeny in air and clouds is transferred into rainwater. It has often been observed that gamma radiation at ground level increases on a rainy day. The increase of natural background gamma radiation disturbs the estimates of the influence of artificial radioactive nuclides from the data obtained using monitoring instruments such as a NaI(Tl) scintillation counter. Excessive effort is required to collect rainwater and measure the radioactivity of nuclides for every rainfall event. In order to overcome the disturbance from the natural radioactive nuclides, we developed a gamma ray monitoring system using a Ge semiconductor detector. The energy resolution of the detector is so high that it can identify the nuclides from the energy information.

In this paper, we describe the characteristics of the monitoring system and discuss the possibility of the determination of radioactivity in precipitation from the data obtained using the system.

MATERIALS AND METHODS

Environmental gamma radiation was measured using a Ge semiconductor detector set up at a height of 1 meter above the ground in a double-shielded tent outside our laboratory. A schematic diagram of the gamma ray measurement system is shown in Figure 1. The exterior of the system is shown in Photo 1.

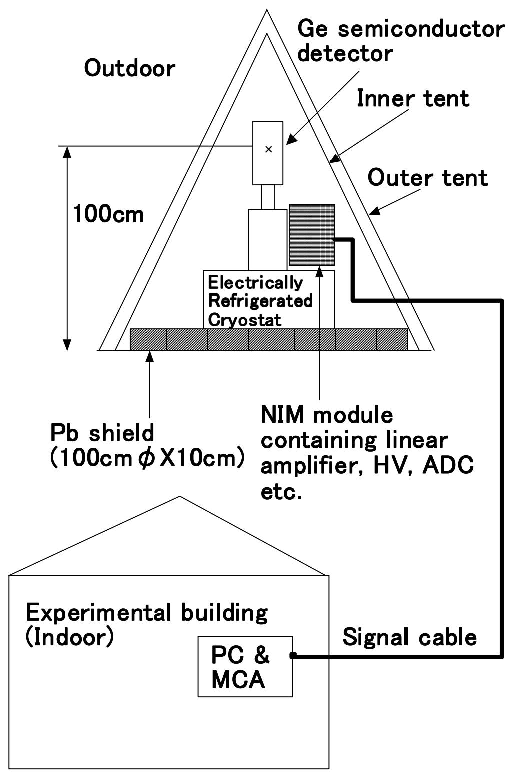

Figure 1. Schematic diagram of the gamma ray monitoring system.

Photo 1. The tent covering the Ge semiconductor detector.

The efficiency of the detector is 65% compared with a NaI(Tl) scintillator of 3-inch diameter and 3-inch length. The atmosphere inside the tent was kept suitable for the operation of the detector through the use of an air conditioner. Gamma ray energy spectra were automatically recorded on a hard disk in a personal computer every 10 minutes. Meteorological parameters (air temperature, relative humidity, wind direction, wind speed, rainfall intensity and volumetric soil moisture content) were also measured every ten minutes.

Concentrations of radon progeny in precipitation were measured using a liquid scintillation counter (LSC) based on the efficiency tracer method (1, 2). Rainwater samples of 50 cc in volume were collected in a 100 cc Teflon vial using a funnel sampler with a one-meter-diameter open face, and mixed with 50 cc LSC-Cocktail (AQUASOL-2: made by A Packard BioScience Company). Concentrations of ^{214}Pb and ^{214}Bi were calculated from LSC count rates of two measurements for 20 minutes after rainwater sampling, assuming that there is no existing ^{218}Po in rainwater.

RESULTS AND DISCUSSION

Environmental gamma radiation using the Ge semiconductor detector was measured during the period from July 1998 to December 1999. During this period, some data were not recorded because of instrumental trouble. The periods of missing data and the cause of the trouble are as follows. 1) From March 3, 1999 to April 12, 1999. The data could not be transmitted to the personal computer because of trouble with the acquisition interface module. 2) From June 20, 1999 to August 26, 1999. Energy spectra could not be obtained because of trouble with the cooling system of the detector. 3) From September 17, 1999 to September 27, 1999. The same reason as 1). A total of four months worth of data could not be recorded during this one and a half year period. In order to achieve stable measurement, improvement of the hardware with regard to these troubles is necessary.

Figure 2 shows examples of the increases of gamma ray count rates from ^{214}Pb (352keV) and ^{214}Bi (609keV) during May 1999. The gamma ray count rate was given by the net count rate (cps) of gamma rays from ^{214}Pb (352keV) and ^{214}Bi (609keV). The figure also shows rainfall intensity (mm/10min) and volumetric soil moisture content (%) at a depth of 10 cm under the ground. It can be seen in the figure that count rates of gamma rays from ^{214}Pb and ^{214}Bi increased during a rainfall. This indicates that these nuclides were supplied to the ground surface around the detector by precipitation.

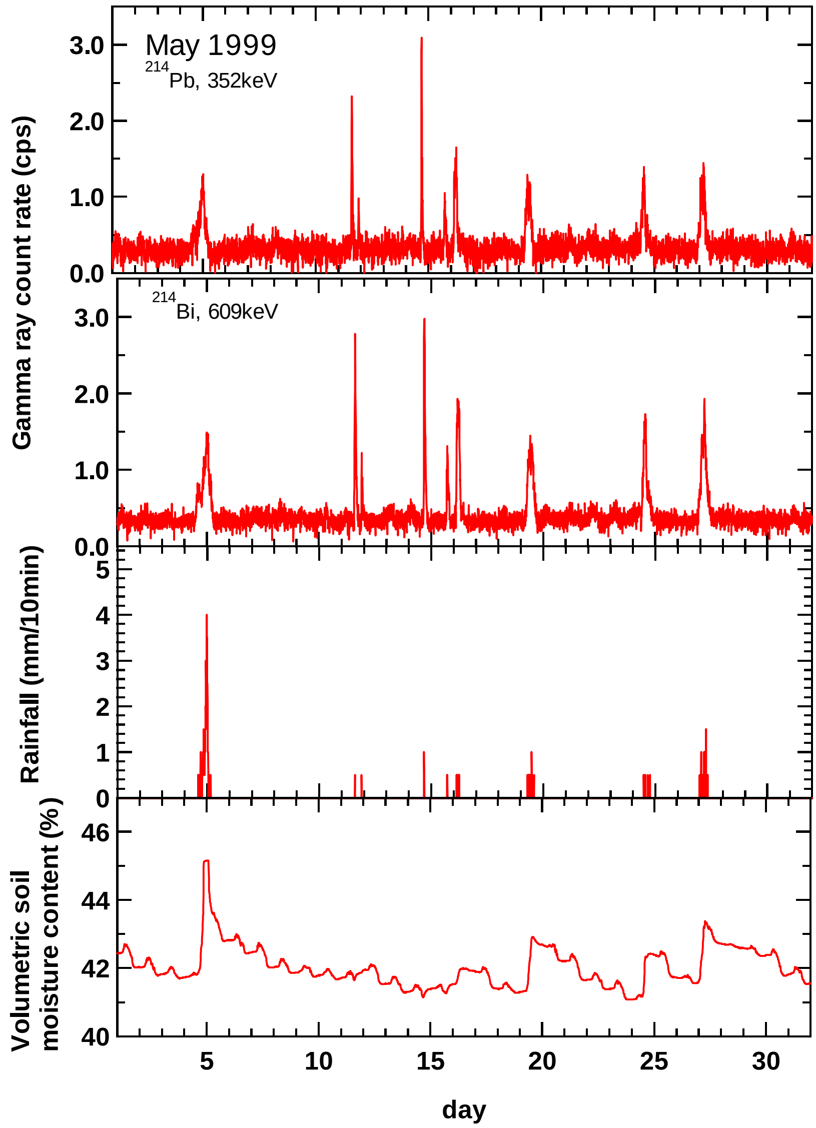

Figure 2. Gamma ray count rates of ^{214}Pb and ^{214}Bi, rainfall and volumetric soil moisture content during May 1999.

Concentrations of ^{214}Pb and ^{214}Bi were calculated from the increase of the gamma ray count rates. The influence of the radon progeny for the preceding three hours was subtracted from the gamma ray count rates averaged over one hour. Radioactivities per unit area (Bq/cm^2) were calculated following the method of Beck et al. (3, 4) and Sakai et al. (5), assuming that radon progeny deposited on the ground surface can be regarded as an infinite-planar source. Radioactivities in precipitation (Bq/cc) were obtained by dividing these values by the rainfall intensity. Concentrations of ^{214}Pb and ^{214}Bi estimated using the Ge semiconductor detector were compared with those obtained by measuring rainwater directly using the LSC. The relationships between the concentrations using the Ge semiconductor detector and the LSC are shown in Figure 3. The coefficients of correlation were 0.65 for ^{214}Pb and 0.77 for ^{214}Bi. Absolute values differed between those estimated using the Ge semiconductor detector and those using the LSC. For ^{214}Pb, the concentrations estimated using the Ge semiconductor detector are about 1.8 times higher than those estimated using the LSC. On the other hand, the concentrations of ^{214}Bi estimated using the Ge semiconductor detector are about 0.6 times smaller than those estimated using the LSC. The causes of the disagreement can be considered to be due to the differences between the actual situation and the assumption that radon progeny deposited on the ground surface can be regarded as an infinite-planar source. For example, 1) rainwater attached to the outer tent surface near the detector may contribute to the increase of the gamma ray count rate, 2) rainwater flows out from near the detector because the ground is covered with grass within a 10-meter radius from the detector and there is an asphalt road more than 10 meters away, 3) rainwater deposited onto trees may contribute to the increase of the gamma ray count rate.

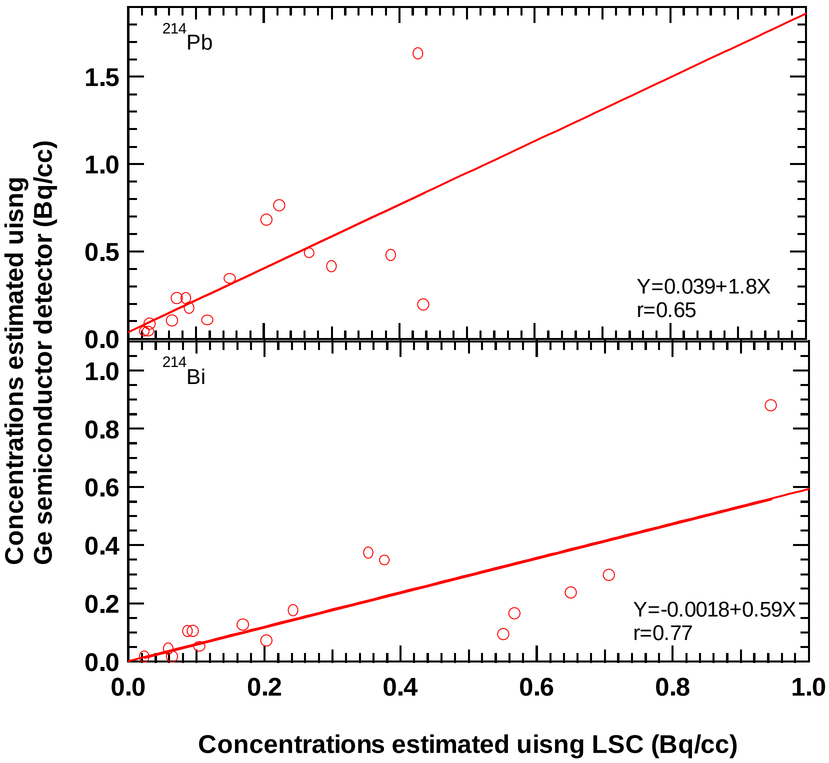

Figure 3. The relationships between ^{214}Pb and ^{214}Bi concentrations estimated using Ge semiconductor detector and liquid scintillation counter.

CONCLUSIONS

Environmental gamma radiation was measured during a period of one and a half years using a Ge semiconductor detector. About one-fifth of the total data could not be recorded because of trouble with the acquisition interface module and the cooling system of the detector. Improvement of the hardware is needed to enable stable measurement. In order to evaluate radioactivity in precipitation using the gamma ray monitoring system, it is necessary to develop a method for correcting the differences between the assumed and the actual conditions. For example, 1) rainwater attached to the outer tent surface near the detector may contribute to the increase of the gamma ray count rate, 2) rainwater flows out from near the detector, 3) rainwater deposited onto trees may contribute to the increase of the gamma ray count rate.

REFERENCES

1. H. Ishikawa, M Takiue and T. Aburai: Int. J. Appl. Radia. Isotopes. 35, 463 (1984)
2. H. Ishikawa: Transactions of the American Nuclear Society, 61, 15 (1990)
3. H. L. Beck, W. J. Condon, and W. M. Lowder: Spectrometric techniques for measuring environmental gamma radiation, HASL-150 (1964)
4. H. L. Beck, J. A. DeCampo, and C. V. Gogolak: In situ Ge(Li) and NaI(Tl) gamma-ray spectrometry, HASL-258 (1972)
5. E. Sakai, H. Terada, and M. Katagiri: In-situ measurement of the environmental gamma-rays by portable Ge(Li) detectors, JAERI-M 6498 (1976)