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Monitoring Method for an Ambient Gamma Exposure Rate and Its Measurement Analysis

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Abstract - Daily and seasonal variations of the ambient gamma ray exposure rates were measured by using a pressurized ion chamber from January 2003 to December 2005 in the CheongJu Regional Radiation Monitoring Post and the patterns of the distributions were studied. The annual average of the daily variation of the exposure rate was ~0.17 μR/h. The exposure rate was found to be maximum during 8:00 am to 9:00 am and minimum during 8:00 pm to 10:00 pm. For the annual data, the exposure rate was the minimum during the month of February. The exposure rate increased from February to mid-October (except during the period from May to July with no change) and decreased from October to February. The seasonal variation was found to be about 1 μR/h. Most of the measured values (96%) of the exposure rates fell under the normal distribution with a deviation of less than 4.8% and the remaining 4% had large fluctuations caused mainly by the rainfalls.
Key words : Ambient gamma, Monitoring, CheongJu post, Exposure rate, Seasonal variation

Introduction

Environmental monitoring for ambient gamma ray exposure is an effective means of assessment of the environmental radioactive contamination, because the exposure rates can be measured quickly at the places where the appropriate detectors are installed [1-3]. The indication of a radiological accident can be had from the increase in the exposure rate over the normal pre-measured value or by comparing the measured exposure rate with that in the other region. As the exposure rate is strongly related to the radioactivity present in the soil, regional / geographical locations (sea side or inland), etc [4,5], it is not possible to ascribe the variation in the exposure rate in a universal way. The exposure rate could change by the variation in the radon concentration in earth surface air due to rain falls or the atmosphere. Shielding of lithosphere radioactivity due to the snowfall or the water content in the soil of the earth surface[6] also influences the exposure rates. Exposure rates become site specific for the places where the detectors are installed. Significant variations in the exposure rates occur seasonally and to a much smaller extent annually. Therefore, it becomes important to observe the exposure rate for a long period of time, to generate the data bank of normal exposure rates at all strategic sites and to establish daily, monthly, seasonally and annually variations by analyzing the distribution patterns to the extent possible.

In the present work the exposure rates were measured continuously at the Environment Radioactive Observation Service in the CheongJu Regional Monitoring Post by using a pressurized ion chamber from January 2003 to

December 2005 and the data was analyzed for the daily and seasonal variations. For the use of even the same detector, the distribution pattern and the variation of the exposure rates are found to be influenced by the frequency of the measurements, therefore, the exposure measurements were made at every 15 min and every one hour.

Material and Methods

Measurement of ambient gamma exposure rate

The activity of the soil samples was measured by HPGe detector with 28% relative efficiency. For recording the daily and seasonal variations of the exposure rates, the detector was located under the Mt. U-Am in CheongJu ChungCheongBukDo Korea. The surface of the detector location was made even and grass was transplanted on it. The exposure rate in air at 1.5 m above the ground, due to radionuclides in the soil, was measured by the ionization chamber (ReuterStokes RS-131). The photon energy dependence of the response of the chamber was known to remain within 20% from 60 keV to 2 MeV and the uncertainty of the measured values was about 5%. The exposure rates were measured at every 15 minute from January 2003 to December 2005. However, no measurement could be carried out for 15 hours from 2 AM of October 31st 2005 due to the failure of electric power supply but there was no impact of this on the performance or on the calibration of the chamber. The measured data flowed and got accumulated in the ASCII code into the PC hard disk through the serial communication cable in real time.

A 4″×4″ NaI(Tl) detector was installed at the 1.5 m above the ground. Gamma ray spectra were measured for 30 minute to obtain information on the energy of the gamma rays around the field in which the detector was located. A multi-channel analyzer having 1024 channels ADC was used. The amplifying gain was set to measure gamma rays of energy up to 3000 keV with 1.7% dead time.

Result and Analysis

1. Characteristic of the gamma ray field

Natural radiation, except cosmic rays, in the air on the earth surface is emitted from the decay of ^{40}K and the products of ^{238}U and ^{232}Th decay series. Figure 1 shows an in-situ spectrum measured by a NaI(Tl) detector. Exposure rate from a spectrum can be calculated by using the peak areas of the representative gamma rays emitted from each decay product. The representative gamma rays of ^{40}K, ^{238}U and ^{232}Th decay series are the photons of energy 1460 keV, 1764 keV and 2614 keV, respectively. For a 4″X 4″ cylindrical NaI(Tl) detector, the formula to calculate the exposure rates of each decay series from peak area (E_1, E_2 and E_3) of gamma ray was presented in the Environmental Measurements Laboratory (EML)[7]. The exposure rates from ^{40}K, ^{238}U and ^{232}Th decay series calculated using this formula were 3.32±0.03, 1.63±0.16 and 3.33±0.06 μR/h, respectively. The levels of these exposure rates are a bit higher than the average exposure rate of 2.0, 1.0 and 2.4 μR/h in USA [4].

Figure 2 shows the impact of rain fall on the exposure rates from 0 hour of April 22, 2003 till 18 hours of April 23, 2003. The exposure rates were calculated from the spectra measured with a 30-minute interval by using NaI(Tl). The rainfall began at 22 hours of April 22 and accordingly, the total exposure

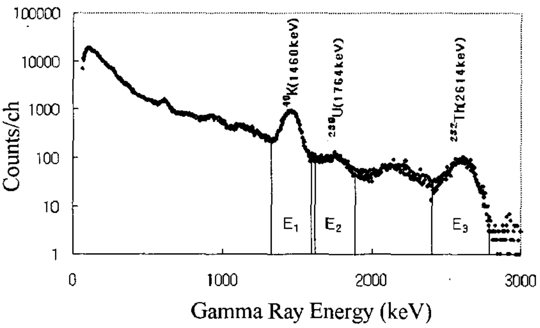

Fig. 1. In-situ spectrum at CheongJu Radiation Monitoring Post on April 22, 2003 measured by 4 ″X 4″ NaI(Tl).

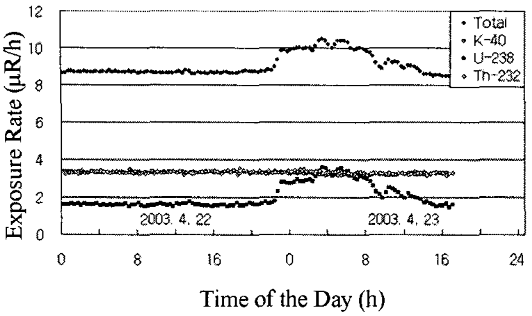

Fig. 2. Variations of exposure during rain-fall.

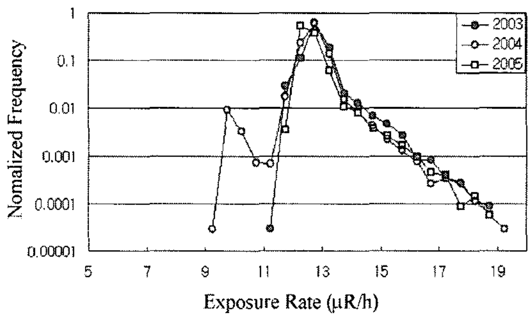

Fig. 3. Distribution of Exposure Rates.

rate increased from 8.7 μR/h to 10.5 μR/h. This increment of the exposure rate is in line with the increment of the exposure from ^{238}U decay series resulting in the observed enhancement of radon concentration in the air on the earth surface by the wash out[8].

2. Distribution of the ambient gamma exposure rate

A total 105,155 measurements of exposure rates were made from January 2003 to December 2005. Table 1 shows the summary of ambient gamma exposure rates. The yearly average value of the exposure rate had a deviation of 0.5 μR/h.

Figure 3 shows a similar pattern for the annually measured data. Most of the values of the exposure values (96% of data) over the relative frequency of 0.01 fell under the normal distribution with a deviation of 0.65 μR/h whereas the remaining 4% values of the exposure rate fell out of the normal distribution. The values out of the normal distribution imply

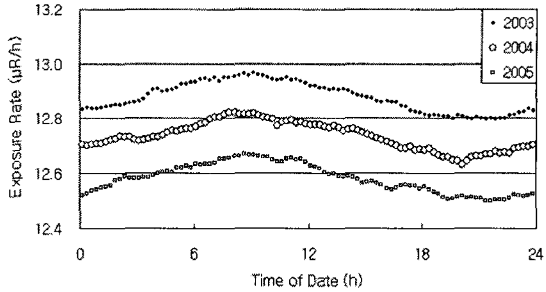

Fig. 4. A diurnal variation of ambient gamma exposure rate.

Table 1. Summary of ambient gamma exposure rate.

Year	No. of Data	Exposure Rate (μR/h)		
		Average	Minimum	Maximum
2003	35040	12.88 ± 0.52	11.5	19.0
2004	35136	12.73 ± 0.57	9.5	19.4
2005	34979	12.58 ± 0.48	11.8	18.8

systematical variations due to the impact of daily and seasonal variations and rainfalls. The exposure rates below 11 μR/h for the year 2004 in Fig.3 are assigned to the shielding of terrestrial radioactivity by snowfall (35 cm) on March 5th 2004[9].

3. Daily Variation of the ambient gamma exposure rate

Figure 4 shows an average value of the exposure rate measured with a 1-hour interval in a day. The differences between the maximum value and the minimum value in the daily variation were 0.17, 0.19 and 0.17 μR/h for the year 2003, 2004 and 2005, respectively. A maximum pick from 8:30 am to 9:00 am and a dip from 8:00 pm to 9:00 pm can be seen in the diurnal variation of ambient gamma exposure rates (Fig. 4). The daily variations of the 1-hour averaged exposure rate are 0.16, 0.17 and 0.16 μR/h for the year 2003, 2004 and 2005. The daily variation for the 1-hour integrated dose value is 0.01 μR/h less than the daily variation of the 15-minute interval measurement. It may be noted that strong relation between the daily variation

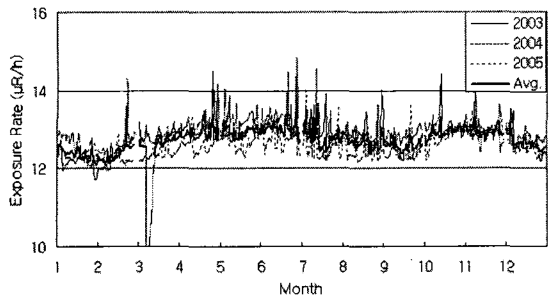

Fig. 5. Seasonal variation of the ambient gamma exposure rate.

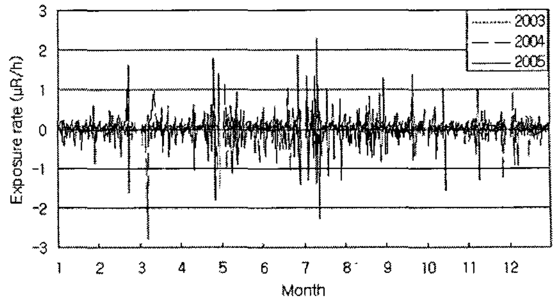

Fig. 6. Time series variation of ambient gamma exposure rate.

of the exposure rate and the variation of the radon concentration in air due to the atmosphere stability[10] is well known.

4. Seasonal Variation of the ambient gamma exposure rate

Figure 5 shows an average value of the exposure rate measured with 1-day interval in the years of 2003, 2004 and 2005. For the annual data, the exposure rate was the minimum during the month of February. The exposure rate increased from February to mid-October (except during the period from May to July with no change) and decreased from October to February. The yearly measurements of figure 5 show a pattern similar to that of the seasonally measured data.

5. Time series variation of the ambient gamma exposure rate.

Since the exposure rate was measured continuously, a characteristic of the time series variation of the exposure rate is an important factor. Fig. 6 shows a difference between the daily average value of the exposure rate and the average value of the last day. As shown in Fig. 6, the reference of the variation is 0 μR/h. We can get the information on the variation of the exposure rate by comparing Fig.5 and Fig.6.

In situations of suspected increase in the exposure rate, many countries like Germany decide on the increase of the exposure rate by comparing the data with the data that was measured a day before. Those data appear to have been used in reference[3]. The present study shows that in the case of a daily averaged data for the exposure rate, the variation of time series is less than ± 3.0 μR/h for the last 3 years.

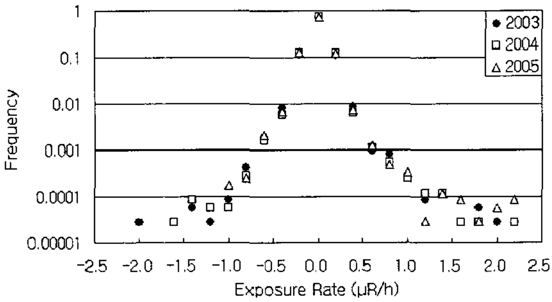

Fig. 7. Distribution of time series variation in ambient gamma exposure rate.

Figure 7 shows the distribution of time series variation in ambient gamma exposure rate that was measured every 15-minute. The distribution of the time series variation in ambient gamma exposure rae is symmetrical about the 0 μR/h, see Fig. 7. The variation in the 95.95% of the measured data is less than ± 1.0 μR/h.

Conclusion

Daily and seasonal variations of the exposure rates were measured in the CheongJu Regional Radiation Monitoring Post from January 2003 to December 2005 using a pressurized ion chamber and the patterns of the distribution were analyzed. Finally it was concluded that:-

1. The 96% of the annually measured exposure rate values fell under the normal distribution with a 4.8% standard deviation. The remaining 4% fell out of the normal distribution due to the fluctuations caused by the rainfalls. The distribution patterns were similar to the data measured in the annual base.
2. The annual average of the daily variations of exposure rate measured at 1-hour interval was between 0.16 and 0.17 μR/h with a maximum pick up during 8:00 am to 9:00 am and a minimum dip during 8:00 pm to 10:00 pm. The daily variation for the 15-minute interval of exposure rate measurements was higher by 0.01 μR/h than that for 1-hour interval.
3. The exposure rate was minimum in the month of February. The exposure rate increased from February to the mid-October (except for May to July with no variation) and decreased from October to February. The size of the seasonal variation was around 1 μR/h.
4. The time series variation could provide more precise method to monitor the environmental radioactive contamination as the distribution of the variation was symmetrical about the 0 μR/h and the variation of 95.95% of the measured data was less than ± 1.0 μR/h.

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