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■ 論 文 ■

Assessment of the terrestrial gamma radiation dose in Korea

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Abstract – The gamma-ray dose rates in air at 233 locations in Korea have been determined. The contribution to the gamma-ray dose rates in air due to the presence of ^{232}Th-series, ^{238}U-series and ^{40}K is as follows: 47.3% (36 nGyh^{-1}) ^{232}Th-series, 14.5% (11 nGyh^{-1}) ^{238}U-series and 38.2% (29 nGyh^{-1}) ^{40}K. The mean gamma-ray dose rate theoretically derived from ^{232}Th-series, ^{238}U-series and ^{40}K was 76±17 nGyh^{-1}. This corresponds to an annual effective dose of 410 μSv and an annual collective dose of 18900 person-Sv for all provinces under study. The results have been compared with other global radiation dose.
Key words : natural radiation; gamma-ray dose rate; annual effective dose; annual collective dose; Korea.

INTRODUCTION

It is possible to establish the radiation dose received by man by calculating the radiation dose levels produced by natural and artificial radionuclides[1]. In the field of radiation protection, our attention has been long focused on artificial radioactivity. Growing attention has been devoted to the effect of natural radioactivity over the past 20 years. About 87% of the radiation dose received by mankind is due to natural radiation sources and the remaining is due to anthropogenic radiation sources [2]. Since natural radiation is the main source of human exposure, studies of the dose from this source and its effects on health improve the understanding of radiation damage. Therefore, it is necessary to attain baseline value or background level on radiation dose level in order to protect the public from potential radioactivity hazard.

The purpose of the present study is to assess the radiation dose to the Korean population from the gamma-ray dose rate. The values of the calculated gamma-ray dose rates due to the presence of the ^{232}Th-series, ^{238}U-series and ^{40}K concentration were compared with the results obtained from the measurements of the gamma-ray dose rates in the air at a height of 1 m above the ground.

MATERIALS AND METHODS

Fig. 1 shows 233 sampling locations and the geographical distribution of the nine administrative provinces in Korea.

Gamma-ray dose rates in the air at a height of 1m above the ground were measured using 3″x3″ NaI (T1) detector (Quantum technology) and a pressurized ionization chamber (RSS-1012/3, Reuter stokes) at the locations where soil samples were taken. The analysis of the gamma spectra obtained by the NaI (T1) detector was performed with dedicated software (GDR_C, Quantum technology). Process that change from gamma spectrum to gamma-ray dose rate is used Energy band Method. Most peaks appeared in gamma spectrum are caused by products of ^{238}U-series,

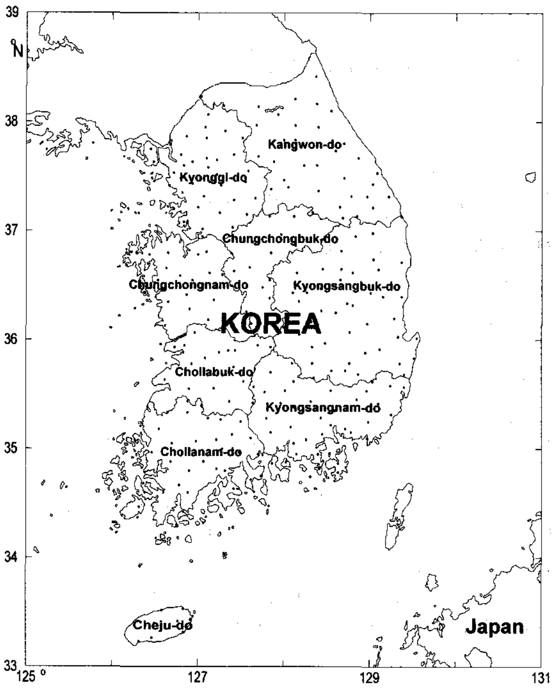


Fig. 1. Map of Korea depicting the geographical distribution of the nine administrative provinces and 233 sampling locations.

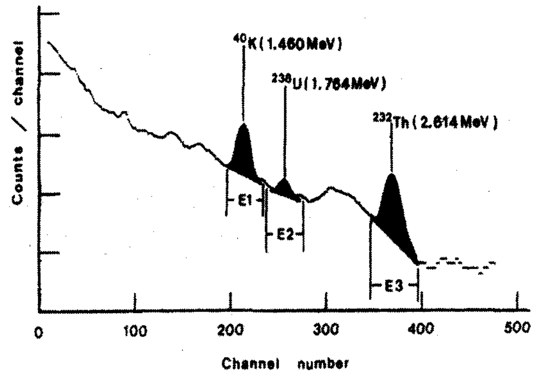


Fig. 2. Energy peak of the 3″x3″ NaI(T1) In-situ spectrum.

^{232}Th-series and ^{40}K. If there is this nuclide series in radioactivity equilibrium, the gamma-ray dose rate from three nuclide that represent three nuclide series can appeared by linear combination of known coefficient and these peak. The peak of ^{238}U-series was evaluated from the gamma-ray 1.76 MeV of ^{214}Bi peak, while 2.61 MeV gamma peak of ^{208}Tl peak was used to determine ^{232}Th-series. The peak of ^{40}K was determined from ^{40}K peak at 1.46 MeV peak (Fig. 2). Gamma-ray dose rates were measured using a counting time of 1800 sec. The measurements were conducted so as to avoid increases or decreases of exposure rates during rainfall or snowfall in order to obtain typical gamma-ray dose rates [3,4]. Gamma-ray dose rates, measured with exposure rates (Rh^{-1}), were converted to gamma-ray dose rates (nGyh^{-1}) in air by multiplying by a factor of 8.66.

To compare the results obtained from the gamma-ray dose rates theoretically derived from the ^{232}Th-series, ^{238}U-series and ^{40}K, we have investigated gamma-ray dose rates in air using the instrument with pressurized ionization chamber (PIC). The gamma-ray dose rates in air from this study were converted to effective dose rates, by multiplying by 0.7 Sv Gy^{-1} [5] and by considering that people in Korea spend on average 12% their time outdoors [6]. In their 1993 report, UNSCEAR[2] assumed that the outdoor occupancy factor was 0.2, implying that on average, around the world, people spend 80% of their time indoors.

Table 1 details the number of samples collected in each of the nine provinces of Korea, along with respective surface areas and population densities. The assessment of the annual collective dose was based on the annual effective dose resulting from environmental radiation and population distributions obtained from 2000 national census information for each province.

RESULTS AND DISCUSSION

Gamma-ray dose rate

The gamma-ray dose rate calculated for the contribution to the gamma-ray dose rate of ^{232}Th-series, ^{238}U-series and ^{40}K in air detected using 3″x3″ NaI (T1)detector and the gamma-ray dose rate measured using PIC at 1 m above the ground were analyzed to derive the estimates in soil for each province and the country as a whole. The gamma-ray dose rates measured using NaI (T1) detector and PIC detector for the 9 province regions of Korea and the whole country are presented in Table 2.

Table 1. Number of soil measurements taken in each province and surface areas and populations of each province of Korea.

Province	Number of measurements	Area (km^2)	Population (millions)[1]
Kyonggi-do	36	11723	21.354
Kangwon-do	33	16613	1.487
Chungchongbuk-do	15	7432	1.467
Chungchongnam-do	22	9137	3.213
Chollabuk-do	18	8051	1.891
Chollanam-do	31	12491	3.349
Kyongsangbuk-do	37	19910	5.206
Kyongsangnam-do	32	12335	7.656
Cheju-do	9	1847	0.513
Total	233	99539	46.136

[1] Obtained from 2000 national census information.

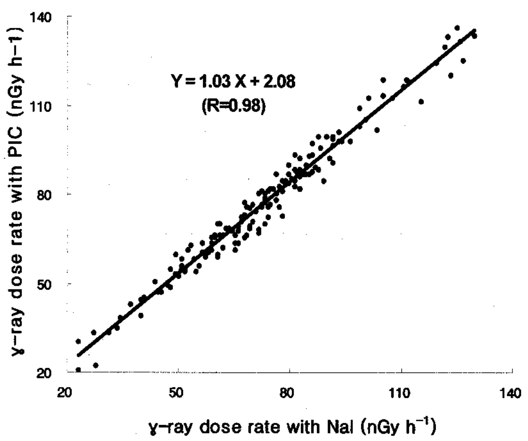
Table 2. The mean of the gamma-ray dose rate using NaI (T1) detector and pressurized ionization chamber (PIC) detector in air for the nine provinces of Korea and the whole country, and the world.

Region	NaI detector ($nGyh^{-1}$)				PIC ($nGyh^{-1}$)
	Th-series	U-series	^{40}K	Total	
Kyonggi-do	50	11	33	94	97
Kangwon-do	38	14	32	84	91
Chungchongbuk-do	41	13	35	89	95
Chungchongnam-do	39	12	30	81	85
Chollabuk-do	33	10	28	71	75
Chollanam-do	40	10	32	82	86
Kyongsangbuk-do	36	10	33	79	76
Kyongsangnam-do	29	10	25	64	70
Cheju-do	17	7	12	36	38
Korea	36	11	29	76	79
World	16.6	10.7	15.5	52.8	55

The background contribution from cosmic rays was 32.0 $nGyh^{-1}$[7]. The mean gamma-ray dose rate from Kyonggi-do, Kangwon-do and Chungchongbuk-do is higher than that in Kyongsangnam-do and Cheju-do. The mean gamma-ray dose rate was the highest in Kyonggi-do (94 $nGyh^{-1}$), while the island of Cheju-do has the lowest rate overall (36 $nGyh^{-1}$) due to it is the parent material of the soil [8].

Table 2 provides a comparison between the gamma-ray dose rate measured with NaI (T1) detector and PIC detector in Korea, and the world average [9]. The contribution to the gamma-ray dose rate from ^{232}Th-series, ^{238}U-series and ^{40}K is as follows: 47.3% (36 $nGyh^{-1}$) ^{232}Th-series, 14.5% (11 $nGyh^{-1}$) ^{238}U-series and 38.2% (29 $nGyh^{-1}$) ^{40}K. The important factor was the contribution from rocks of high thorium and potassium content [8]. The mean gamma-ray dose rate of 76 $nGyh^{-1}$ for the whole of Korea was comparable with that of 79 $nGyh^{-1}$ measured with PIC in air.

The relationship of gamma-ray dose rates measured with NaI(T1) and PIC detector can be inferred by means of cross-correlation analysis and the equation of fitted straight line. Fig. 3 shows a scatter diagram of the gamma-ray dose rates measured with NaI(T1) and PIC detector. The equation (gamma-ray dose rates with NaI (T1) detector = 1.03 gamma-ray dose rates with PIC detector + 2.08) of fitted straight line is indicating that the gamma-ray dose rates with PIC are on average 3% higher than the gamma-ray dose rates with NaI (T1). The cross-correlation coefficient between gamma-ray dose rate measured with NaI (T1) and PIC detector in 233 locations was 0.98. The agreement between measured gamma-ray dose rates derived from 3″x3″ NaI (T1) detector and PIC detector was good in all of the samples surveyed.



Annual effective dose and annual collective dose

The mean gamma-ray dose rate calculated for the contribution to the gamma-ray dose rate from ^{232}Th-series, ^{238}U-series and ^{40}K is 76 nGyh^{-1}. The mean gamma-ray dose rate in air of 76 nGyh^{-1} corresponds to an annual effective dose of 410±93 Sv. The annual effective dose in Korea is slightly lower than the 450 μSv estimated by UNSCEAR[2] for the world mean using 0.7Sv Gy^{-1} and 0.8 for the conversion coefficient and the occupancy factor, respectively. The annual effective dose for all of the measurements varied between 136 and 762 μSv. In Korea, the lowest provincial mean annual dose was 194 μSv and the highest provincial mean annual dose was 508 μSv for the Cheju-do and Kyonggi-do provinces, respectively (Table 3). The corresponding annual collective dose was 18900 person-Sv, with values ranging between 100 (Cheju-do) and 10800 person-Sv (Kyonggi-do).

Table 3. Annual effective dose and annual collective dose for the nine provinces of Korea.

Province	Annual effective dose equivalent (μSv)	Annual collective dose equivalent (person-Sv)
Kyonggi-do	508	10800
Kangwon-do	454	674
Chungchongbuk-do	481	705
Chungchongnam-do	437	1400
Chollabuk-do	383	725
Chollanam-do	443	1480
Kyongsangbuk-do	427	2220
Kyongsangnam-do	346	2650
Cheju-do	194	100
Total	4082	18900

CONCLUSIONS

From the measurement of the gamma-ray dose rate at 233 locations in Korea, we have calculated gamma-ray dose rate, annual effective dose, and annual collective dose for each province and the country as a whole.

The contribution by each of the radionuclides ^{232}Th-series, ^{238}U-series and ^{40}K to the external gamma-ray dose rate was 47.3% (36 $nGyh^{-1}$), 14.5% (11 $nGyh^{-1}$) and 38.2% (29 $nGyh^{-1}$), respectively. The mean of the gamma-ray dose rates using NaI (T1) detector at 1m above the ground was 76 $nGyh^{-1}$, excluding the contribution from the cosmic rays. The annual effective dose for all provinces under study and the corresponding annual collective dose, when the duration of outdoor exposure and distribution of the population were considered, were 410±93 μSv and 18900 person-Sv in Korea, respectively.

These results will provide a valuable and useful reference for the design and development of studies in specific regions of Korea that show enhanced levels of radiation.

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