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Dose Assessment of High-Level Radiation Region in the Okchun Belt

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Abstract

The uranium-riched region(Geosan) was carefully monitored for two years and the monitoring data were analyzed to estimate the environmental radiation dose to the inhabitants. The exposure pathways were defined and effective doses were calculated using monitoring data. The radon inhalation is the most important pathway to the population. Except the radon inhalation dose, the environmental dose to inhabitants living in the uranium-riched region is not so different from those of average level of Korea.

1. Intorduction

Radioactivity of natural origin arises from primordial radionuclides and their daughter products. These natural radionuclides spread over all around environments and give a radiation effect to man via internal and external pathways. Among natural sources uranium is widely distributed in the earth crust and it rarely exists in significantly enriched form in soils and rocks. The health condition of the inhabitants in uranium riched region is usually concerned in view of radiation protection. While there have been these natural nuclides since the beginning of earth existence, man-made nuclides have recently released from nuclear installations. Although the artificial radionuclides around nuclear facilities like nuclear power plant are carefully monitored the general public require the solid evidences to ensure the safety in their daily life. As an explainable mean to these complains the health condition of population being highly exposed to natural radiation is often compared as the reference cases. The Okchun Metamorphic Belt which is covered with low uranium-bearing black shales has been studied by environmental researchers in recent year[1]. The average content of uranium in Okchun shale is about 250 μg/g. This value is higher than the content of uranium in any other regions of Korean peninsula. In this work to assess the environmental radiation dose due to natural radiation sources, small towns, Geosan, which located in the Okchun Belt and near a closed coal mine which have once produced low grade coal bearing enriched uranium, was carefully monitored for two years(2001-2002). The radiation dose were estimated with pathway analysis using the monitoring data and the related problems were discussed.

2. Monitoring program

The environmental monitoring program covered 14 small towns within the about 5 km radius from the closed coal mine in the Okchun Belt, which located in the central part of South Korea. The monitoring site is mountainous area composed of small forest hills and valleys. The 45 sampling points were set up considering geomorphology and living environment of inhabitants(population number of about 2,500). Air dust, precipitation, soil, surface water and underground water are periodically sampled. Food samples are also taken in harvest season to monitor the ingestion pathway. The gamma emitting nuclides were measured with gamma-spectrometry system equipped with HPGe and uranium isotopes were alpha-ray spectrometer after chemical separation of uranium. The accumulative environmental doses were measured using the thermoluminescence dosimeter(TLD). Radon activity of indoor air were measured with E-

PERM(Electric passive environment radon monitor) for radon inhalation dose estimation.

3. Exposure pathway for dose calculation

Considering the exposure pathways, the annual effective dose is calculated as followings:

$$H_E = \Sigma \, \Sigma H_{pr} \qquad (1)$$

where
H_E is the effective dose ; Sv/y
H_{pr} is the effective dose of nuclide r through pathway p.

The exposure pathways to man are considered as followings

3.1 Internal dose caused by ingestion of food

Five groups of food including drinking water were taken into consideration. The dose calculation equation caused by ingestion of contaminated food is

$$H_{gr} = \Sigma \, \Sigma G_{gr} \quad C_{rf} \quad U_f \qquad (2)$$

where
H_{gr} is the effective dose by ingestion of nuclide r, Sv/y;
G_{gr} is the effective dose conversion factor by ingestion of nuclide r, Sv/Bq, [2];
C_{rf} is the activity concentration of nuclide r in ingested food, Bq/kg or Bq/l;
U_f is the consumption rate of food f, kg/y or l/y.

3.2 Internal dose from radionuclides inhaled with air

The inhalation dose of nuclide r depends on the nuclide concentration of the air at the place under consideration. The dose calculation equation is

$$H_{hr} = \Sigma G_{hr} C_{ar} V \bullet 10^{-3} \qquad (3)$$

where
H_{hr} is the effective dose by inhalation of nuclide r, Sv/y;
G_{hr} is the effective dose conversion factor by inhalation of nuclide r, Sv/Bq[2];
C_{ar} is the activity concentration of nuclide r in air, mBq/m^3;
V is the respiratory rate of air, m^3/s

3.3 Internal dose by radon inhalation

The effective dose were calculated with the equation given by UNSCEAR1993 report[3].

$$H_{Rn} = G_{Rn} C_{Rn} T \quad F \bullet 8760 \qquad (4)$$

where
G_{Rn} is the effective dose conversion factor, 9 x 10^{-9} Sv/(Bq h m^{-3})
C_{Rn} is the radon activity concentration, Bq/m^3
F is the equilibrium constant: indoor 0.4, outdoor 0.6
T is the ratio of residence time: indoor 0.9, outdoor 0.1, (8,760 hr/y)

3.4 External dose from outside sources

External dose exposure was caused by several sources including beta-/gamma-submersion from surrounding air, ground shining from soil and cosmic ray. Here we assumed that the accumulated gamma dose measured by TLD represent a total external dose.

4. Dose calculation results and discussion

The monitoring data was carefully reviewed to calculate the environmental dose. The available data to calculate the environmental dose from the monitoring program was shown in Table 1, which also include rice, chinese cabbage, egg and milk as food stuffs. Activity concentrations in Table 1 are the annual average value in the monitoring area. Natural and artificial radionuclides including the gamma-emitters, uranium and radon were monitored and compiled as detection limits or measured values. In Table 1, almost all of nuclide concentration in samples was measured as detection limits except several nuclides like K-40, Cs-137, Be-7 and uranium. The activity of U-238 in the soil of surveyed area is not so higher than expected. This average value is within a activity variation of Korean soil(15 – 65 Bq/kg)[4]. The measured values only were used to calculate the dose. Food consumption rates used for the calculation of ingestion dose are shown in Table 2. It is assumed that the inhabitants consume the food harvested in the monitoring area and use the underground water as drinking water.

The dose estimation in this study was carried out on the basis of annual effective dose per capita for adults. The ingestion dose due to food consumption was estimated in about 82 μSv/y, which was entirely caused by K-40. This value is slightly higher than average of other area of south Korea[5]. The site-average dose due to inhalation of air dust is 0.23 μSv/y, which is mainly attributed to uranium. The year-average radon concentration was 139.0 Bq/m^3, while the maximum value was 402.9 Bq/m3. It is 2.6 times higher than average indoor radon activity across Korea. The recent study have reported that the

Table 1.Nuclide concentration in environmental monitoring samples around Geosan site.

nuclide	Rice	Chinese cabbage	Egg	Milk	Drinking water	Air	Soil
	Bq/Kg - fresh	Bq/Kg - fresh	Bq/Kg - fresh	Bq/l	Bq/l	Bq/m^3	Bq/Kg - dry
U-238	1.91×10^{-3}	11.2×10^{-2}	<MDA	<MDA	1.8×10^{-3}	1.2×10^{-6}	68.1
Be-7	<MDA	0.5	<MDA	<MDA	<MDA	1.6×10^{-3}	5.8
K-40	30.2	89.2	<MDA	53.9	<MDA	<MDA	754.5
Cs-137	<MDA	0.52	<MDA	<MDA	<MDA	<MDA	5.8
Rn-222	-	-	-	-	-	139.0*	-
TLD	116 mR/yr						

* indoor radon

Table 2. Food consumption rate and air respiratory rate(adult).

Food	Consumption rate	
Grain	141.0	Kg/y
Vebetable[1]	87.3	Kg-fresh/y
Egg[2]	7.6	Kg/y
Milk	19.6	l/y
Drinking water	532.5	l/y
Respiratory rate	7,313.0	m^3/y

1 leafy, root and fruit vegetable

2 egg and poultry

average radon activities of indoor and outdoor across Korea were 53.4 and 23.3 Bq/m^3, respectively[6]. The radon inhalation dose was 4.1 mSv/yr considering 23.3 Bq/m^3 of national average outdoor concentration. The environmental dose measured with TLD was 116 mR/y, which was influenced by all radiation source in the vicinity of monitoring post including ground radiation, radon and cosmic rays. The TLD dose of 116 mR can be converted into 100.9 mrad. As the annual cosmic radiation in central part of Korea was reported as about 28.7 mrad[7], the terrestrial gamma radiation dose can be assumed as 72.2 mrad. The annual external dose measured with TLD can be converted into 0.7 mSv using a conversion factor of 0.7 Sv/Gy[8].

The annual effective dose of inhabitants was about 4.9 mSv/y considering above pathway analysis. The radon inhalation is the most important pathway to the population. The above 80% of annual dose 4.9 mSv was due to radon. It was interesting that the high level radon concentrations were detected in the houses near the closed coal mine. What caused the radon accumulation in these houses should be investigated further. The internal dose caused by inhalation of air dust was very negligible. Hence although the natural radioisotope, K-40, in foods was a major radiation source to man via ingestion pathway, the ingestion pathway is not important to total radiation exposure. Except K-40, nuclides such as Be-7, U-238 and Cs-137 made little contribution to ingestion dose. The environmental TLD dose in the surveyed region was within the range of national average. As the TLD dose considered here as an external dose was largely attributed to gamma radiation, the additional external dose by beta-radiation can be added slightly. But the radiation dose by beta-ray submersion may be negligible.

As a whole result in this study, except the radon inhalation dose, the environmental dose to inhabitants living in the urainium-riched region is not so different from those of average level of Korea. In case of radon, the further study should be carried out to trace the origin of indoor radon and to assess the health risk of population. To estimate the health effect, the epidemiological study in this area is going on.

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