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Uranium Levels in Soil and Plant, and Estimation of Its Intake by the Residents at the Uranium Deposited Area

우라늄광 부근에서 우라늄의 토양 및 식물체중 함량과 주민들에 의한 체내 집적량추정

柳長杰 · 宋基俊* · 金台淳**
濟州大學, 한국煙草硏究所*, 한국原子力硏究所**

Zang-Kual U, Ki-Joon Song* and Tai Soon Kim**
Jeju University, Korean Tobacco Research Institute,*
Korean Atomic Energy Research Institite**

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요 약

우라늄광이 분포되어 있는 충청북도 괴산군 덕평리 일대의 26개 지점에서 토양 및 식물체를 채취하여 우라늄 함량을 정량하였다. 한편 이 지역에서 생산되는 농작물을 주식으로 하고 있는 주민들의 인체내 우라늄 누적량을 추정했다.

토양중 우라늄 함량은 4.9ppm~43.6ppm으로 평균 15.5ppm이었으며 이 값은 대조구로 조사된 경기도 양주군 금곡리와 이천군 준일리의 우라늄 함량보다 3배 정도 높았다.

식물체의 경우는 평균 0.69ppm으로 대조구보다 약 2배 많았다. 덕평리 마을의 성인 한 사람이 이곳의 농산물로부터 만들어진 음식물에서 섭취하는 일당 우라늄량은 247μg으로 추정되었으며 이 값은 0.83×10^{-4} uCi의 방사능에 해당되며 뉴욕 시민의 1.3μg에 비해 훨씬 높았다.

그러나 체내에 누적되는 우라늄의 방사능량은 $2.03\times10^{-4}\mu$Ci으로 국제 방사선 방어협회가 보고한 최대 허용 체내 집적량 0.2uCi보다는 훨씬 낮은 값이었다.

Introduction

There has been increasing interest in documenting the levels of natural isotopes in man, his diet and environment, especially in the uranium deposited area.

Deogpyeongri, known to be an uranium deposited area, is a counrty village with 132 households consisted of 548 men and 515 women. This area contains Guryongsan-layer of weathered sedimentary rock which consists of mainly black slate, phyllite, dark gray chlorite, and schist. Also it is reported that the average content of uranium at coalmine sites is 76.7ppm. The farmers' annual crop productions amount to 160 M/T of barley, each 24 M/T of bean and red bean, 16 M/T of corn, 30 M/T of potato, 20 M/T of tobacco, and 12M/T of red pepper.

The possible intake amount of uranium through food-chain was estimated by determining the contents of uranium in the farming soils and some crops sampled from Deogpyeongri, Goisangun, Chungcheongbug-do.

Experimental Methods

a) Soil samples

As shown in Table 1, the soils were collected from 23 farmer's fields of Deogpyeongri and adjoined Daejeonri, dried, ground to pass 100 mesh sieve and determined for uranium by the neutron activation analysis.

Table 1. Sampling sites and sample numbers of soil and plant

Site Number	Places	Sample no. of plants
1	Deogpyeongri-san 17	1-Barley, 1-Bean
2	Deogpyeongri-jeon 41	2-Barley, 2-Bean, 2-Red Bean, 2-Corn 2-Indian millet
3	Deogpyeongri-jeon 13	3-Barley, 3-Corn, 3-Indian millet, 3-Red pepper
4	Daejeonri-jeon 48-2	4-Barley
5	Deogpyeongri-dab 240	5-Barley, 5-Rice
6	Daejeonri-jeon 314	6-Barley, 6-Bean
7	Deogpyeongri-dab 2-3-1	7-Barley, 7-Rice
8	Deogpyeongri-jeon 16	8-Barley, 8-Red Bean 8-Corn
9	Deogpyeongri-jeon 264	9-Barley, 9-Bean, 9-Indian millet
10	Daejeonri-jeon 110	10-Barley, 10-Bean, 10-Corn,4, 10-Sesame
11	Daejeonri-j eon 13	11-Barley, 11-Bean, 11-Corn
12	Deogpyeong-jeon 117-3	12-Potato, 12-Red pepper, 12-Perilla
13	Deogpyeong-jeon 215	13-Potato, 13-Bean
14	Deogpyeong-jeon 206-1	14-Potato, 14-Red Bean, 14-Red pepper
15	Daejeonri-jeon 315	15-Potato, 15-Bean, 15-Red bean, 15-Coru
16	Degpyeongri-jeon 241	16-Garlic, 16-Red pepper
17	Deogpyeongri-jeon 109	17-Garrlic, 17-Red pepper, 17-Perilla
18	Deogpyeongri-jeon 161	18-Barclic, 18-Sesame
19	Daejeonri-san 1	19-Garlic
20	Deogpyeong-dab 196	20-Rice
21	Deogpyeong	21-R e
22	Yangjugun Migeummyeon	22-Baley, 22-Bean, 22-Red Bean, 22-Potato 22-Red peppe
23	Icheongun Junilri	23-Baley, 23-Potato
24*	Deogpyeongri	24-Pine needle, 24-Oak leaves 24-Mugwort
25*	Deogpyeongri	25-Pine needle, 25-Oak leaves 25-Mugwort
26*	Deogpyeongri	26-Pine needle, 26-Oak leaves 26-Mugwort

*Sampled only plants

Table 2. Uranium contents of the soils

Site No.	Uranium (ppm)	Site No.	Uranium (ppm)
1	36.4	13	15.5
2	28.7	14	14.6
3	20.2	15	11.2
4	18.9	16	11.5
5	18.4	17	10.7
6	17.8	18	12.0
7	15.8	19	14.2
8	12.9	20	15.0
9	8.9	21	5.3
10	4.9	22	5.4
11	43.6	23	4.8
12	15.8		

b) Plant samples

Plants samples were also taken from the fiie-ds where the soil samples were collected except the site No. 24, 25, and 26. (sec Table 1). After drying at 75°C, a 10 gram of dried matter was weighed out, ashed in the furnace of 450°C and determined for uranium.

c) Uranium determination[2)]

A 100~200mg portion of the sample was accurately weighed and sealed by heating in a small polyethylene bag for irradiation. A stock solution of uranium was prepared by dissolving 0.210g of A.R. grade $UO_2(NO_3)_2$-$6H_2O$ in 5ml of 0.1N nitric acid and diluting with distilled water to 100ml in a volumetric flask.

Irradiation was carried out by the pneumatic transfer system of TRIGA MARK III reactor.

Table 3. Uranium contents of the plant samples

Sample No.	Uranium (ppm)	Sample No.	Uranium (ppm)	Sample No.	Uranium (ppm)
1-Barley	0.21	4-Barley straw	1.05	9-Barley straw	1.19
1-Barley straw	0.55	5-Barley	0.25	9-Bean	0.87
1-Bean	0.36	5-Barley straw	0.97	9-Indian millet	0.56
2-Barley	0.22	5-Rice	0.90	10-Barley	0.55
2-Barley straw	0.42	6-Barley	0.89	10-Barley stiaw	1.29
2-Bean	0.81	6-Barley straw	1.30	10-Bean	0.72
2-Red Bean	1.04	6-Bean	0.40	10-Corn	0.25
2-Corn	0.26	7-Barley	0.48	10-Sesame	1.51
2-Indian millet	0.78	7-Barley straw	1.19	11-Potato	1.29
3-Barley	0.21	7-Rice	0.96	11-Potato leaves	2.38
3-Barley straw	0.34	8-Barley	0.28	11-Bean	0.30
3-Corn	0.23	8-Barley straw	0.45	11-Corn	0.29
3-Indian millet	0.23	8-Red Bean	0.35	12-Potato	1.10
3-Red pepper	0.74	8-Corn	0.35	12-Potato leaves	2.05
4-Barley	0.37	9-Barley	0.27	12-Red pepper	0.53
12-Perilla	0.56	16-Red pepper	0.53	23-Barley	0.26
13-Potato	0.39	17-Garlic	1.24	23-Barley straw	0.34
13-Potatoleaves	1.47	17-Red pepper	0.42	23-Potato	0.23
13-Bean	0.41	17-Perilla	0.81	24-Pine needle	0.65
14-Potato	1.27	18-Garlic	0.38	23-Oak leaves	0.85
14-Potato leaves	1.44	18-Sesame	1.08	24-Mugwort	0.66
14-Red Bean	0.46	19-Garlic	0.75	25-Pine needle	0.36
14-Red pepper	0.46	20-Rice	0.33	25-Oak leaves	0.76
15-Potato	0.57	21-Rice	0.21	25-Mugwort	0.57
15-Potato leaves	1.18	22-Barley	0.19	26-Pineneedle	0.62
15-Bean	0.26	22-Bean	0.65	26-Oak leaves	0.32
15-Red Bean	0.66	22-Red Bean	0.30	26-Mugwort	0.21
15-Corn	0.20	22-Potato	0.67		
16-Garlic	0.33	22-Rice	0.23		

The position of irradiation is located at the face of the reactor core. At the power level of 1MW, the thermal neutron flux was 1.0×10^{13} neutrons cm^{-2} sec^{-1} and the unmoderated fission flux was 2.6×10^{12} neutrons cm^{-2} sec^{-1} at the irradiation position. Samples were received for counting within 6~8 sec after the end of irradiation.

Results and Discussion

a) Uranium contents of the soils

Uranium contents varied with the fields; two fields above 30ppm, another two fields 20ppm to 30ppm, 14 fields 10ppm to 20ppm, and the rest five fields below 10ppm as shown in Table 2. The soil samples from Geumgog and Junil taken as control area gave 5.4ppm and 4.8ppm of uranium contents. It seems that there si a relationship between the soilcolors and uranium contents; the darker, the higher amounts of uranium. The reason is that the soil color depends on the contents of carbonious materials containing uranium.

b) Uranium contents of the plant samples

The uranium analysis showed that there was no relationship between uranium concentratiolns of the soils and those of plant samples. It is expected, however, that the uranium concentration of the soils may affect the absolute amounts of uranium uptake by the plants even if it did not the uranium con-

Table 4. Uranium contents of the plant samples in Deogpyeongri and control areas

Plants	Uranium contents(ppm)				
	Deogpyeongri, Goisangun			Geumgog, Yangjugun	Junil, Icheongun
	Max.	Min.	Mean.		
Rice	0.96	0.21	0.60	0.23	
Barley	0.89	0.21	0.37	0.19	0.26
Barley straw	1.30	0.34	0.88		0.34
Bean	0.87	0.26	0.52	0.65	
Corn	0.35	0.20	0.26		
Indian millet	0.78	0.23	0.52		
Sesame & Perilla	1.51	0.56	0.99		
Red Bean	1.04	0.46	0.67	0.30	
Potato	1.29	0.39	0.92	0.67	0.23
Potato leaves	2.38	1.18	1.70		
Red pepper	0.74	0.42	0.54		
Pine needle	0.65	0.36	0.54		
Oak leaves	0.85	0.32	0.64		
Mugwort	0.66	0.21	0.48		
Average	1.02	0.38	0.69	0.36	

Table 5. Estimation of uranium intake per person through daily food stuffs at Deogpyeongri area

Crops	*Daily Intake per person (g)	**Average Uranium contents of crops (ppm)	***Daily Uranium Intake per person(ppm)
Rice	244	0.6	134.7
Barley	263	0.37	89.5
Bean	5.0	0.52	24
Red Bean	0.5	0.67	0.3
Corn	3.0	0.26	0.7
Potato	68	0.92	12.5
Garlic	7.2	0.37	0.8
Red Pepper	13	0.54	6.4
Total	603.7		247.3

*Based on "The average consumption pattern of rural country" reported by the Ministry of Health and Social Affairs(in air dried matter)

**Average values from the present study (75°C dried matter)

***Calculated by corrected values from air dried to 75°C dried matter.

centration.

Table 3 indicates that most of plants gave 0.5ppm to 0.6ppm of average uranium concentration, while potato, sesame and barley straw showed higher values and corn had the lowest value, 0.26ppm. In case of barley and potato there was a tendancy that the leaves contained higher levels of uranium than the grains or the edible part of plants. On the other hand, the uranium concentration of the plant samples from control area, Geumgog and Junil of Gyeonggido, ranged from 0.19 to 0.67ppm as shown in Table 4. These values are less than half the uranium levels of plants grown in Deogpyeong area.

c) Estimation of uranium intake through food stuffs

Daily intake of uranium through the foods by Deogpyeong residents was calculated based on the average food consumption pattern of rural country reported by the Ministry of Health and Social Aflairs. Table 5 presents the data. 247μg of uranium equivalent to 0.83×10^{-4} μCi, is estimated to be daily uptaken by an adult resident having taken the agricultural food stuffs produced in Deogpyeong area. It was reported that the daily intake of uranium per person in New York city was 1.3μg uranium/day and in Russia the daily intake of uranium ranged from 12.6 to 304μg.[1)]

ICRP[4)] reported that, usually, about 1.9μg of uranium was daily uptaken through foods and drinking water. The reason why the daily intake of uranium by Deogpyeong residents gives about 200 times that of New York citizen, is that average uranium content of whole grains (0.5ppm) in Deogpyeong area gives much higher value than that of U.S.A. (0.003ppm). Also drinking water of Deogpyeongri presented 4μg of uranium per liter while the average value of U.S.A. was 0.03$\mu g/l$.[1)] But it is noticeable that uranium levels of crops in control areas give rather higher values comparing to those of U.S.A.. The fact that such higher levels of uranium presented as background in

the surveyed control areas should be investigated furthermore throughout the country with more detailed and expanded project.

d) Estimation of internal uranium accumulation through the food-chain

The possible effect of internal uranium accumulation on the resident's health was taken into consideration referred to maximum permissible burden in total body recommended by ICRP. The constants employed for the calculation[5] of total uranium(Q) accumulated internally at equilibrium time, were based on the ICRP report.[3] If effective half-life, T_e, is assumed 100 days and the absorption rate, f_1, 1%,[2]

$$Q=Pf_1\ (1-e^{-\lambda t})/\lambda$$

provided that P : amount of daily uranium intake (μg) per person

λ : decay constant of uranium in the body, and given as $\frac{0.693}{T_e}$

t : elapsed time (day)

If an adult would intake 247μg of uranium daily through the food stuffs for 10 years continuously,

$$Q=247\times\frac{1}{100}(1-e^{-0.03/100\times10\times365})/\frac{0.693}{100}$$

But $e^{-25.3}$ being negligible,

$$Q=247-0.693=357\mu g\ U$$

Converting$Q$ to radioactivity

$$357\mu g\ U=357\times3.36\times10^{-7}\mu Ci$$
$$=1.2\times10^{-4}\mu Ci$$

This calculation indicates that $1.2\times10^{-4}\mu$Ci of uranium intaken via food-chain could be accumulated in the human body. Since the excretion period is, in general, considered to be 24 hours, one day's diet remains in the intestines at all times and the radioactivity of $0.83\times10^{-4}\mu$Ci($=247\times3.36\times10^{-7}\mu$Ci) from daily diet should be added to $1.2\times10^{-4}\mu$Ci, making $2.03\times10^{-4}\mu$Ci, which is totally loaded radioactivity of uranium in the body. But the value of $2.03\times10^{-4}\mu$Ci appears to be about one thousandth the maximum permissible burden in total body, 0.2μCi, recommended by ICRP.

Although the calculated level of internal uranium intake for the Deogpyeongri residents seems to be rather below the critical value, the actual amount of uranium intake would be much higher than the calculated value because not so little uranium could be inhaled through the respiratory system with the soil dust or involved into the body via drinking water.

Since there are, at present time, lack of the fundamental data about internal contamination of radioactivity for the occupational workers or non-occupational persons in this country, the actual levels of uranium in each organ of human body should be investigated and furthermore the constants such as effective half-life or absorption rate also ought to be determined in accordance with the physical characteristics of Korean people.

Summary

The soils and plants were sampled from 26 sites of Deogpyeongri, Goisangun, which had been found to be one of the uranium deposit areas. Uranium levels of the samples were determined and the amount of uranium intake by the residents through the food-chains was estimated.

The average uranium concentration of Deogpyeongri soils was 15.5ppm with a range of from 4.9 to 43.6ppm showing rather higher values than those of control area, Yangjugun and Icheongun, Gyeonggi-do. The average uranium content of the plant samples from Deogpyeongri was 0.69ppm, about twice the uranium concentration of the control samples.

The daily intake of uranium by an adult lived on the agricultural food stuffs produced in Deogpyeongri, was estimated to be about 247μg, eqivalent to $0.83\times10^{-4}\mu$Ci, which is much higher activity compared to the daily intake of uranium by New York citizen, 1.3 μg. However the calculated uranium level accumulated in the human body of Deogpyeong area was $2.03\times10^{-4}\mu$Ci which is still lower

than 0.2μCi, the maximum permissible burden in total body recommended by the ICRP.

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