

Determination of Sr-90 in the Vertebrae of Reference Korean*

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표준 한국인 척추골내의 Sr-90 함량 측정에 관한 연구

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Abstract

The determination of Sr-90 in 93 Korean vertebrae was carried out using modified method of tri-n-butyl phosphate extraction. As a result, the average content of Sr-90 in Korean vertebrae was 2.29 pCi/g Ca in the female and 1.73 pCi/g Ca in the male and the average level of both sexes was 2.01 pCi/g Ca, which was slightly higher than those of other countries.

On the other hand, the Sr-90 injected into intraperitoneal cavity of rat was accumulated in bones mostly and distributed evenly to various types of bones. The rate of accumulation and removal was not dependent on the amount of Sr-90 injected and over one half Sr-90 injected was accumulated in bones within one day and then it was removed gradually after two days from the injection.

요 약

Tri-n-butyl phosphate를 이용한 Sr-90의 정량법에 전처리 과정을 도입시킨 방법을 적용하여 한국인 93명의 척추골내 Sr-90의 함량을 측정하였다. 그 결과 Sr-90의 함량은 여자의 경우 2.29 pCi/g Ca로 나타났고, 남자의 경우 1.73 pCi/g Ca로 나타났으며 남녀 전체적으로 2.01 pCi/g Ca의 평균값을 나타내 외국의 경우보다 다소 높은 값을 나타내었다.

한편 쥐의 복강내에 Sr-90을 주입시켜 각 골조직내의 Sr-90함량을 측정한 결과 주입된 Sr-90은 골조직의 종류에 상관없이 골고루 분포되었으며 주입된 전체 Sr-90의 약 반이 1일 이내에 각 골조직에 침적되었으며 그 이후 점차적으로 제거되는 것을 관찰할 수 있었다.

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1. Introduction

Since Sr-90 has been known to be a radionuclide with very long biological half life and a major product of nuclear fission, many countries have studied the level of Sr-90 in human vertebrae and applied the obtained data to establish the annual limit of radionuclide intake in accordance with the increase of nuclear facilities. Such efforts are collected in UNSCEAR report.¹⁾ By the report, the average value of Sr-90 in vertebrae of the race is different from those of other countries because of differences existing in their life habitats. However, the Sr-90 level in Korean vertebrae has not yet been reported, though the nuclear facilities increase abruptly in Korea. It was, therefore, tried to measure the level of Sr-90 in Korean vertebrae and also to study the accumulation and removal of the radionuclide taken up in the rat as an experimental animal.

2. Methods

The determination of Sr-90 on 93 Korean vertebrae which were collected from the domestic medical colleges was carried out by the modified method of that described in HASL-300.²⁾ That is, the sample ashed (5g) in muffle furnace at 900°C for 24 hours dissolved in 50 ml of concentrated nitric acid and the yttrium dissolved in nitric acid solution was extracted twice with 30 ml of tri-n-butyl phosphate. The aqueous phase was left for two weeks and 1 ml of yttrium carrier solution (20 mg yttrium/ml) was then added to that solution. The yttrium in nitric acid solution was transferred to 50 ml of tri-n-butyl phosphate twice. Total 100 ml of tri-n-butyl phosphate was washed with 50 ml of 14 N HNO₃. Finally, the yttrium in tri-n-butyl phosphate was extracted twice with 50

ml of distilled water and the acidic solution was neutralized with NaOH pellets. After the pH of the solution was adjusted to 8.0 with ammonium hydroxide solution, the precipitate was separated from supernatant by centrifugation (10 minutes at 1,500 g). The precipitate was dissolved with a few drops of 1 N HCl, then added 1 ml of saturated oxalic acid. The precipitate was filtered on Toyo 5B filter paper and dried at 105°C for 2 hours. The filter paper was mounted on 1 inch disc and its radioactivity was measured with low background β counter (Tennelec LB-5100 ; USA) for 30 minutes for each sample. On the other hand, the calcium contents in human vertebrae were determined using atomic absorption spectrophotometer (Varian AA-175 ; USA) after the samples were dissolved in 5N Nitric acid. The wavelength and the slit width for the measurement were 422.7 nm, 0.5 nm, respectively.

Sr-90 removal from experimental animal was studied after the injection of 5 μ Ci of Sr-90 (SrNo₃;5 μ Ci/ml) to intraperitoneal cavity of a rat. At some days after the injection, the rats in each group (4-8 rats) were decapitized and their bones were removed. The bones were ashed in muffle furnace at 900°C for 24 hours. Twenty mg of ashed sample was dissolved in concentrated HNO₃ and the solution was transferred to one inch planchet. The solution was dried under IR lamp and the radioactivity was measured, using portable ratemeter scaler (Everline PRS-1 ; USA), for 10 minutes.

3. Results and Discussion

As mentioned in introductory part, the contents of radionuclides in human bodies might be different between races because of differences existing in habitat, custom and food consumption between them. Many countries, therefore, have devoted much efforts to determine

Table 1. Sr-90 Content in Korean Female Vertebrae

Age	Ca content (mg/100mg ash)	Sr-90 (pCi/Ca)
45	35.5	1.89
40	31.9	2.78
50	34.0	0.50
48	32.5	0.58
20	33.0	1.89
65	34.0	0.42
20	37.0	3.31
20	33.5	0.12
88	34.5	0.92
71	35.5	0.21
60	36.0	2.74
59	34.0	0.22
80	36.2	2.52
45	37.3	3.84
48	29.9	0.49
83	32.6	5.33
80	34.2	0.61
32	31.2	3.57
85	41.0	1.30
20	34.8	0.61
16	37.0	4.85
60	31.8	2.09
70	35.7	1.62
69	39.1	0.48
85	36.9	0.05
83	37.1	2.97
20	36.1	0.80
20	20.2	0.11
60	41.0	2.80
67	37.0	1.62
40	34.0	3.06
70	34.0	0.62
67	30.0	1.75
65	34.0	4.87
45	30.0	2.14
56	39.0	2.77
62	34.0	2.94
56	34.0	2.54
58	47.0	1.29
56	34.0	2.48
63	34.0	3.06
60	31.0	2.52
57	36.0	3.60
68	39.0	6.12
71	31.0	7.53

59	38.0	4.60
64	38.0	4.34
Average	34.84±4.09*	2.29±1.72*

* Average±S.D.

the level of a radionuclide in their bodies to evaluate the impact of man-made radionuclide intakes.¹⁾ Among radionuclides produced in nuclear facilities, Sr-90 is a major one and its biological half life is very long but the determination of Sr-90 in human bones is not easy because of the high content of calcium in bones. Therefore, the removal of calcium from strontium is a critical step in the determination of Sr-90 in human bones. One method for the separation between them is based on the difference in solubilities of strontium and calcium in fuming nitric acid solution (17.2 N).⁴⁾ But the method has many defects such as low chemical yield and difficulty in dealing with fuming nitric acid. The alternative method is based on the separation of Y-90 equilibrated with Sr-90 using tri-n-butyl phosphate. Since the final precipitate of yttrium can be contaminated with other radionuclides in samples, the sample dissolved in 14 N nitric acid solution was pre-treated with tri-n-butyl phosphate for the removal of contaminants which might be existed. In the preliminary step, strontium loss was not detected and most of other radionuclides was eliminated (data are not shown). After the treatment, the solution was left for two weeks for the growing of Y-90 and then Y-90 which was grown from Sr-90 was determined. As shown in tables 1 and 2, the average content of Sr-90 in Korean vertebrae was 2.29 pCi/g Ca in the female and 1.73 pCi/g Ca in the male, and the average level of both sexes was 2.01 pCi/g Ca in 93 Korean vertebrae.

On the other hand, the average level of calcium in ashed vertebrae was 35.21% which is lower than that in the foreign data and this phenomenon might be caused by the incomple-

Table 2. Sr-90 Content in Korean Male Vertebrae

Age	Ca content (mg/100mg ash)	Sr-90 (pCi/g Ca)
44	35.0	2.01
55	30.2	1.83
52	34.4	2.06
35	31.5	4.32
43	41.3	1.41
40	32.0	4.86
20	32.0	0.97
48	32.0	0.22
20	32.0	0.81
20	32.0	1.49
20	37.5	2.85
20	34.0	0.22
20	37.5	2.55
55	37.0	1.09
20	31.5	9.54
54	37.0	0.05
52	35.0	1.91
20	30.3	0.46
60	38.5	3.53
20	36.8	2.34
20	40.2	0.12
50	40.3	0.12
20	37.0	0.42
20	34.6	0.86
20	36.1	0.10
67	41.0	1.14
54	37.0	0.73
70	33.0	3.00
54	28.0	1.66
72	37.0	0.89
75	35.0	1.69
66	41.0	0.86
70	42.0	1.78
58	35.0	1.08
58	36.0	0.08
70	48.0	0.75
30	41.0	1.18
65	33.0	2.02
72	40.0	2.00
72	45.0	1.64
63	32.0	0.14
35	39.0	3.16
56	34.0	4.34
70	40.0	2.03
55	35.0	1.42

64	39.0	2.05
Average	35.58±6.01*	1.73±1.65*

* Average±S.D.

tion of ashing process.

According to the UN report,¹⁾ the concentration of Sr-90 in Korean vertebrae was lower than those in Norwegian and Nepalese but higher than those in other countries as shown in Table 3. Those difference in Sr-90 content among races might be caused by the differences in habitat, customs and food consumption patterns among races. The relationships between life environment and the concentration of Sr-90 in human vertebrae can be deduced from a few phenomena indirectly. For example, first, the total amount of Sr-90 in northern hemisphere was 12.13M Ci whereas that in southern one was 3.81M Ci in 1975 and Sr-90 content in vertebrae of men who are living in northern hemisphere was higher than that of one living in southern hemisphere according to the UN report.¹⁾ Secondly, Sr-90 contents in human vertebrae had been varied according to the testing of nuclear weapons. Third, the contents of Sr-90 in herbivorous animals was higher than that in omnivorous or carnivorous animals and the concentration of Sr-90 in animal food was lower than that in vegetable one. These

Table 3. Sr-90 Content in Korean and Foreign Vertebrae

Country	Sr-90 Activity (pCi/g Ca)
Korean (1982)	2.01
Japan (1975)	1.00
U.S.A. (1975)	1.10
Canada (1969)	2.20
France (1973)	1.50
Nepal (1975)	3.00
Norway (1975)	2.80
U.K. (1970)	1.30
Argentina (1972)*	1.20
Australia (1975)*	1.00

* Southern Hemisphere

Table 4. Sr-90 Content and Percent Distribution in the Vertebrae and Total Bone of 8 Week Old Rat as a Function of Time after the Injection of 5 μ Ci of Sr-90

Days after injection	Sr-90 nCi/g ash	Sr-90 μ Ci/g Ca	% distribution	
			Vertebrae	Bone
1	591.98	1.60	10.39	61.07
5	454.48	1.23	7.98	46.89
10	283.95	0.77	4.99	29.32
15	314.22	0.85	5.52	32.43
20	265.14	0.72	4.66	27.40
30	294.15	0.80	5.17	30.38
60	243.92	0.66	4.28	25.15
	(224.89)*	(0.61)	(3.96)	(23.27)
75	168.24	0.46	2.95	17.33
	(160.09)*	(0.43)	(2.82)	(16.57)
90	146.10	0.39	2.57	15.10
	(157.57)*	(0.43)	(2.77)	(16.27)

Remark: *, values obtained by using 12 week old rat

facts support the hypothesis which had a positive relationships between Sr-90 content in animal vertebra and environment. Such phenomenon can be explained with Sr-90 transfer kinetics⁵⁾ also.

Age dependency on the content of Sr-90 in Korean vertebrae could not be detected in our results, because most of them are the vertebrae of adults (except one).

On the other hand, the Sr-90 injected into intraperitoneal cavity was distributed evenly to various types of bones. The rate of accumulation and removal of Sr-90 in rat bone was summarized in Table 4. This result implies that over 50% of Sr-90 injected be accumulated in bones within one day and it will be removed gradually after another one day. This result accords with those results reported previously.³⁾ Such a phenomenon was also occurred in the case of 1 μ Ci of Sr-90 injection.

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