방사선방어학회지
제7권 제1호 1982

Studies on the Reference Korean and Estimation of Radiation Exposure Dose

—PHYSICAL STANDARD AND ESTIMATION OF INTER-EXTERNAL RADIATION EXPOSURE DOSE—

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Abstract

For the purpose of establishment of Reference Korean and estimation of internal and external exposure doses in the Reference Korean, we have surveyed reference values for Koreans, such as physical standards including height, weight and body surface area, food consumption rate of daily intake of radioactive substances and exposure dose from natural radiation.

The results obtained are as follows:

1) The age group of the Reference Korean ranged from 20 to 30 years old in both sexes. The height, weight and surface area of the body of the Reference Korean are 167cm, 61kg and 1.67m^2 in male and 155cm, 51kg and 1.51m^2, respectively in female.
2) The food consumption of the Korean is 812.8g (669.6g of vegetable food and 143.2g of animal food) per capita per day.
3) Koreans are taken about 1,200 pCi of radioactive substances(β-ray) per capita per day.
4) The external and internal radiation exposure doses of the Korean are estimated to be 127 mrem and 8 mrem per year, respectively. However, it is believed that these values will be modified upon the addition of data collection.

Introduction

Most of the peoples are devoted much attentions to the pollution of natural environment by the radioactive substances released from the nuclear facilities, and the human being has become to have much chances of exposure to radiation according to the increase of peaceful uses of atomic energy, recently.

Since the radiation is known as one of the main factors to induce the mutation, cancer and life shortening of animals including human beings there have been a strong effort to establish the degree of maximum permissible exposure dose of radiation.

There are two ways in the exposure of radiation such as, one is the external exposure to the cosmic ray, environmental radiation and radiation released directly from the nuclear facilities such as a nuclear power plant and the other one is the internal exposure from the inhalation or ingestion of natural or man-made radioactive substances through the food chains.

Since 40 units of nuclear power plants are planned to be built and operated in Korea by 2000 precise evaluation of radiological impacts on human population is absolutely essential and necessary.

If quantitative data about the behavior of radioisotopes in the environment, bioaccumulation factors, and the daily intake and metabolism of elements is available, the estimation of internal radiation exposure needed to evaluate the radiological impacts on human populations would be theoretically possible.

With these viewpoints, Committee II of the International Commission on Radiological Protection has compiled human characteristics such as anatomical, chemical and physiological values of man as "Standard Man" (1). Later, upon addition of supplementary data, the committee has recompiled the data as "Reference Man" (2). Japanese investigators have collected their specific anatomical and chemical data since 1970 because their habitat and customs are different from those of Caucasians who are objectives for the Reference Man. In the estimation of radiation exposure doses when the levels are sufficiently low, Reference Man or Reference Japanese (3) values can not directly applicable to the Korean population because of differences existing between races and environments. Disregarding the differences in body characteristics and customs lead to erroneous results in the evaluation of radiological impacts on Koreans. Thus, local specific data is needed to obtain the precise estimation of radiation exposure doses for a given Korean.

In our laboratory, a program for "The Establishment of Maximum Permissible Dose for Reference Korean" was planned in 1980 and now it is in progress. The program on the Reference Korean is composed of the determinations of anatomical, chemical, and physiological characteristics, and of habitat and customs of the normal Korean. In 1980, we carried out the data collection on body length, body weight, body surface area, pattern of food consumption and the quantity of daily intake of radioactive substances. Moreover, because some studies show correlation of background radiation with health, the determination of the effect of man-made radiation to natural background radiation is necessary. We have carried out the estimation of internal and external exposure doses from food consumption and natural background radiation together with the establishment of physical standards for the normal Korean.

METHODS

1. Survey on the Korean physical standards and the estimation of body surface area for Koreans

Physical standards for Koreans (height and weight) were determined on the basis of the survey data by the Korea Advanced Institute of Science and Technology (4), on report of the Normal Data Editing Committee (5) and on the direct survey data. The total number of persons surveyed for the determination of physical standards were 16,977 (male-9,958, and female-7,019) and their surface areas were calculated by Costeff's equation (6).

2. Determination of total β-ray activity in various foodstuffs

Twelve kinds of foodstuffs containing grain were collected three times from 7 different localities in Korea (Fig. 1) to determine their beta radioactivities. The samples collected were dried at 110°C for 2 hours and ashed at 450°C for 12 hours. For each step, the weight of samples were checked. 100 mg of ashed sample was spread uniformly on a round filter paper (Toyo 5A, diameter-50mm) covered with Mylar film (duPont), and mounted on Teflon disc (46×3mm). The total β-ray activity of each mounted sample was determined using low background counter (Tennelec LB-5100).

3. Survey on the food consumption rate

The data was obtained by visiting individual houses and by utilizing the weighing method (7) which 9 meals in a row measures directly each foodstuff consumed for the time of the visit. The number of households and persons for the survey were 180 and 879, respectively. The households for the survey were selected randomly from the entire county and the survey was performed for 3 days at each household. Food intake value per capita per day was calculated from the surveyed data for each foodstuff and each foodstuff was placed in 8 food groups. Nation-wide food intake rate was calculated on the basis of regional values.

4. The estimation of internal and external radiation exposure dose for Korean

Many data such as the intensity of cosmic rays and environmental radiation, and radionuclide contents in various foodstuffs are needed for the estimation of internal and external radiation exposure doses by natural background radiation. Until now, local specific data has been scant in Korea. Therefore, foreign data was extrapolated to the Korean situation for the estimation.

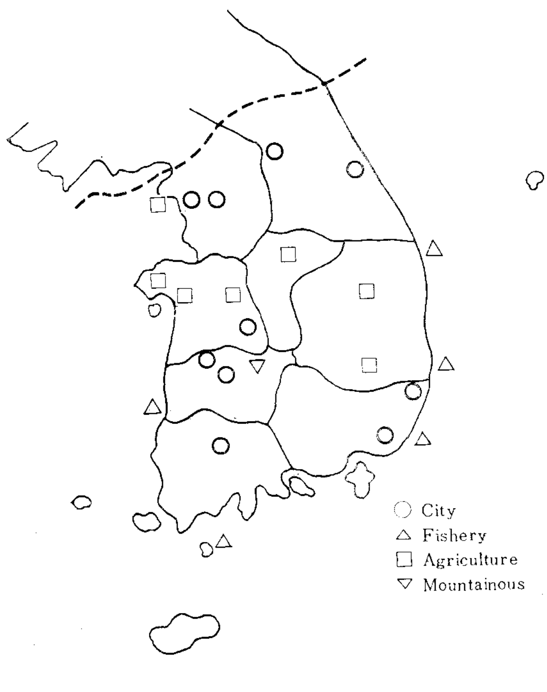

Fig. 1. Locality surveyed for food consumption in Korea (1980)

RESULTS AND DISCUSSION

1. Age group of Reference Korean

In the report of ICRP (2), the task group expressed that it was not feasible to define Reference Man as an "average" or a "median" individual of a specified population group. However, they have attemped to define Reference Man as a reasonably typical individual as far as can be judged from the available data.

With this viewpoint, we decided that the age group of the Reference Korean is 20 to 30 years old in both sexes. physical standards in this range are relatively stable. This age group for Reference Korean is the same as that for Reference Man whereas the age group for Reference Japanese (3) is 20 to 50 years old.

2. Physical standards and surface area of Reference Korean

Total body length and weight for Korean males and females as a function of age in comparison between our data, data for Reerence Japanese (3) and data selected from the report of ICRP (2) were given in Fig. 2, 3, 4 and 5. As shown in Fig. 2 and 3, the total body lengths of Reference Korean are 167cm in male nnd 155cm in female.

In the case of total body length, lower values were found in Korean (3cm in male and 5cm in female) than in Caucasian. Higher values were found in Korean (2cm in male and 3cm in female) than in Japanese (3). However, total body lengths of Japanese presented by the Ministry of Health and Welfare were 167cm in male and 155cm in female which are same as those for Reference Korean. It is believed that the difference between total body lengths in Reference Korean and Reference Japanese is caused by the differences in the time of survey (Korea-1979, Japan-1974) (3) and in the range of reference age group.

The weights of the Reference Korean are 61kg

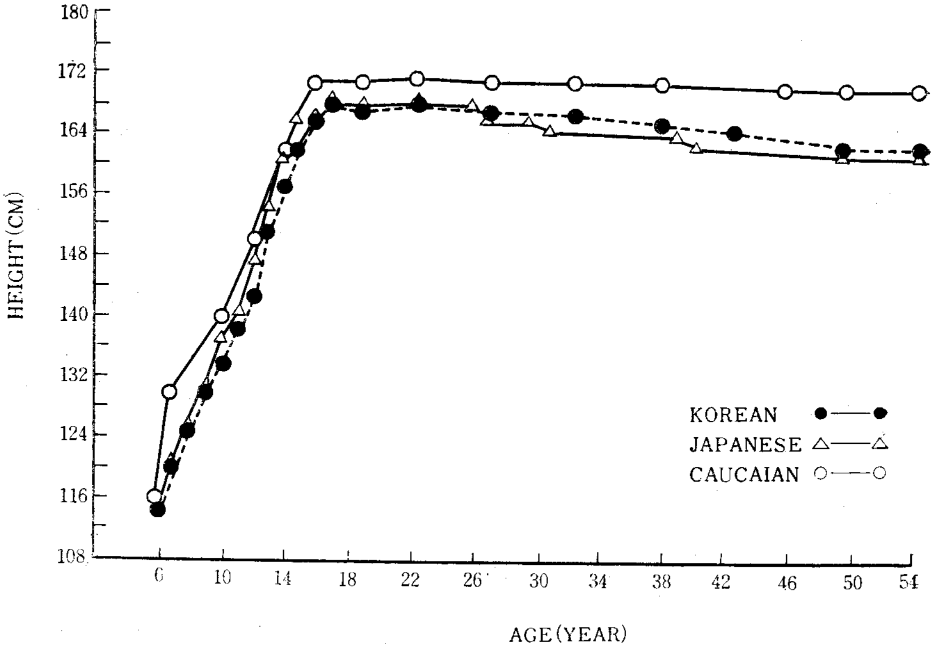

Fig. 2. Height of Korean, Japanese and Caucasian (male)

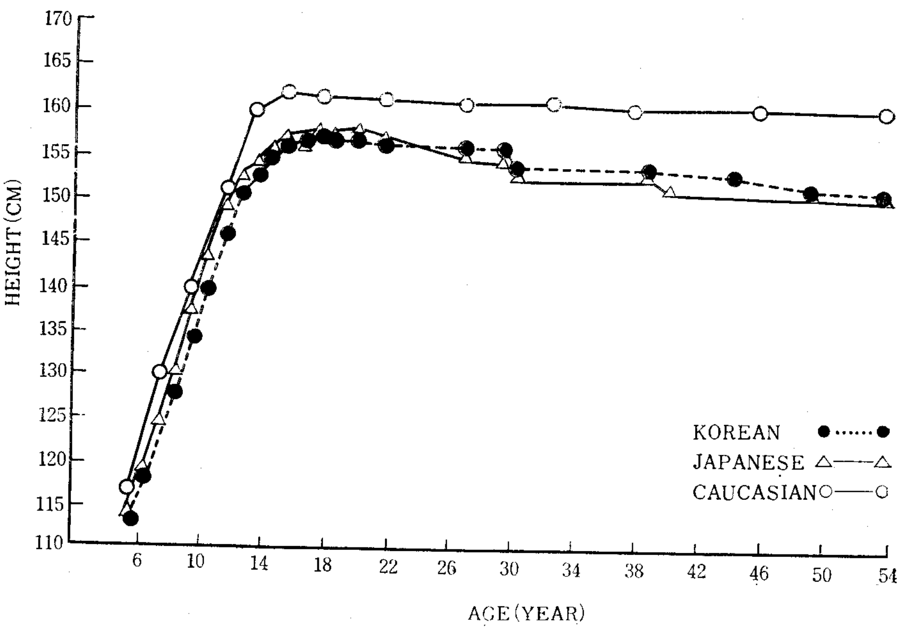

Fig. 3. Height of Korean, Japanese and Caucasian (female)

in male and 51kg in female as shown in Figures 4 and 5. The total body weights of Reference Man are 70kg in male and 58kg in female and those for Reference Japanese are 60kg in male and 51kg in female. As mentioned previously, physical standards for Reference Korean are generally lower than those for Reference Man but are similar to those for Reference Japenese.

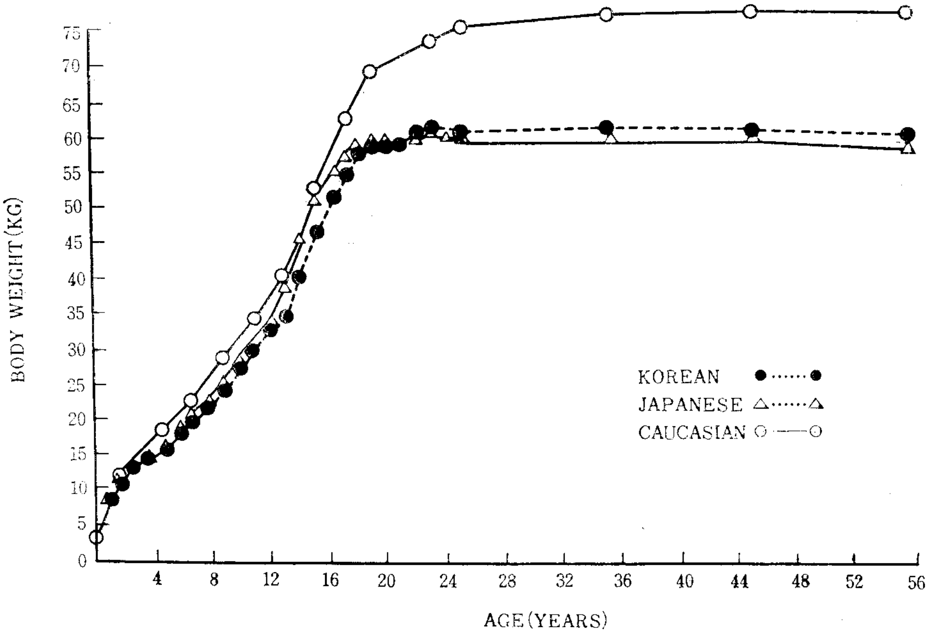

Fig. 4. Total body weight of Korean, Japanese and Caucasian (male)

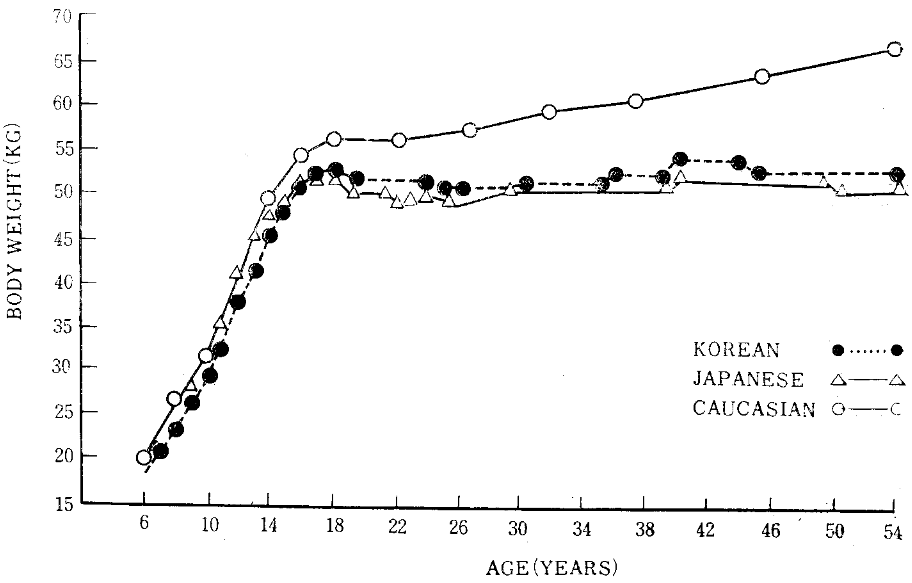

Fig. 5. Total body weight of Korean, Japanese and Caucasian (female)

Accordingly, the statement by Tanaka and Kawamura (8) that results for the Japanese population may be useful in estimating characteristics of other populations in Asia, seems to be reasonable.

Surface area of Reference Korean was calculated by Costeff's equation (6) though many equations (9, 10) were developed to estimate approximate surface area. Costeff's equation was selected among various equations because of the correlation between calculated values and partial measured data. The surface area for Reference Korean calculated by this equation were 1.67m² in male and 1.51m² in female. These values are lower than the values for Reference Man by 0.13m² in male and 0.09m² in female.

Table 1. Total β-ray activity measured from various foods in Korea (1980)

(Unit : pCi/g ash)

Food \ Collection site	Gyema	Mooju	Daejun	Bugu	Chungju	Yeosu	Busan	Mean±S.D.
Rice	196	143	—	159	203	217	171	182±26
Barley	161	—	236	245	202	257	246	224±33
Soybean	294	176	329	274	250	267	270	266±43
Soybean sprouts	241	242	200	280	258	—	277	250±27
Beef	229	106	260	231	258	219	252	222±50
Pork	225	77	176	277	248	177	265	207±64
Chicken	170	85	17	—	22	—	—	74±62
Fish	63	141	293	166	138	—	—	161±70
Clam	113	37	43	161	86	127	146	102±45
Seaweed	171	121	—	220	173	143	214	174±35
Chinese cabbage	247	304	318	324	219	229	248	270±41
Radish	—	313	132	238	352	299	242	263±71

Remark: — Not tested

Table 2. Average food intake per capita per day in Korea and Japan

Food group \ Country	Intake (g)		% distribution	
	Korea ('80)	Japan ('76)	Korea	Japan
A. Vegetable foods				
1. Cereals	408.5	336.3	50.3	36.2
2. Potatoes	17.9	63.3	2.2	6.8
3. Pulses	52.6	68.5	6.5	7.4
4. Vegetables	182.8	259.8	22.5	28.0
5. Seaweeds	7.8	5.5	1.0	0.6
B. Animal foods				
6. Meats	54.1	64.4	6.7	7.0
7. Eggs	23.4	40.3	2.9	4.3
8. Fishes & shells	65.7	90.1	8.1	10.0
Total, Vegetable foods	669.2	733.4	82.4	79.0
Total, Animal foods	143.2	194.8	17.6	21.0
Grand total	812.8	928.2	100.0	100.0

3. Total β-ray activities in various foodstuffs

Twelve kinds of Korean representative foodstuffs were collected from all over the locality and their β-ray activities were determined. As shown in Table 1, the β-radioactivity of each foodstuff was similar to those from other places in spite of small differences according to sampling sites. The average β-ray activities were 203 pCi/g ash for grains, 258 pCi/g ash for beans, 168 pCi/g ash for meat, 161 pCi/g ash for fishes, 102 pCi/g ash for shells, 174 pCi/g ash for seaweeds and 267 pCi/g ash for vegetables. A significantly lower values were found for fishes in Korea when compared to those in Japan (11, 12) whereas higher value was found in Korea when compared to those in China (13). However, other values in Korea were similar to those in China or Japan.

4. Food consumption rate for Korean

The food consumption rate for Korean was compared mainly with that for Japanese and the results are shown in Table 2. On the whole, higher consumption rates in grains and seaweeds were found in Korean compared to Japanese but lower values in other food groups such as meats, fishes, beans etc. were found in Korean. A Korean intakes 666.9g per day in vegetable food and 143.2g per day in animal food whereas a Japanese intakes 733.4g per day in vegetable food and 194.8g per day in animal food (14). As stated previously, there is a big difference between food consumption rate for Korean and that for Japanese. This is the main reason to establish a site specific, typical individual, that is, reference man. Also, intake rate for radiactive materials was estimated on the basis of our direct surveyed data on food consumption rate and on the total β-ray activity in various foods.

Table 3 shows that Reference Korean intakes about 1,200 pCi of β-radioactive materials per day. However, it is dangerous to apply to the estimation of exposure dose by the intake rate of radioactive materials because this has no consideration for the differences between the biological half lives of a radionuclides contained in foodstuffs.

5. Internal and external radiation exposure doses for Reference Korean

1) External exposure dose

A) Exposure dose by cosmic radiation

Although the estimation of the dose equivalent received from cosmic radiation has been difficult in Korea because of the lack of data as well as because of uncertainties in the neutron spectrum, the dose equivalent from cosmic radiation for Korean was estimated by the extrapolation of UNSCEAR report (15) to the Korean situation. Previously, the relative intensity of cosmic radiation at sea level for Korean land to American land was estimated to be 0.97 by Millikan (17) and dose equivalent at sea level in USA was determined by Oakley (16). Therefore, the dose equivalent at sea level in Korea was estimated to be 32.8 mrem per year by electron and muon components and 5.1 mrem per year by neutron components. The dose equivalent for Reference Korean was estimated to be 39 mrem per year taking into account average altitude of Korean habitat because dose equivalent from cosmic radiation varies according to the changes of altitude as well as the geographical longitude and latitude.

Table 3. Total activities of various foods intake per capita per day

Food	Intake weight (g)*	Total activity (pCi)
Rice	354.5	585.20
Soybean	11.2	193.32
Soybean sprouts	23.0	67.30
Beef	29.5	33.68
Pork	18.4	18.01
Fish & shell	52.0	100.15
Chinese cabbage	58.6	121.19
Radish	28.8	52.11
Seaweed	7.8	18.58
Others	229.0	—
Total	812.8	1,189.54

*Data from our survey (1980)

However, this value might be corrected upon the availability of supplementary data.

B) Exposure dose by terrestrial radiation

Based on the reports on UNSCEAR (15, 21) and on the report by Lowder and Solon (18), the dose equivalent by terrestrial radiation for Reference Korean was calculated. By the reports, the main sources of external exposure are K-40, U-238 and Th-232 among primordial radionuclides. Also, acidic granite has higher typical activity concentration of the radionuclides compared to the other common rocks.

Since Korean common rocks mainly composed of acidic granite and granite gneiss (19), the dose equivalent by terrestrial radiation for Reference Korean was found to be 128 mrem per year. However, human beings are not living on common rocks but on soil, and the soil condition varies according to climate. In summary, taking into account Korean soil features, climatelogical condition, etc., the total dose equivalent by terrestrial radiation for Korean was calculated to be 87.7 mrem per year with a range from 60 to 120 mrem per year. This value is slightly higher than those in foreign countries (20, 23).

The dose equivalent of passenger at the altitude (altitude : 30,000ft) was estimated to be 0.79 mrem under average solar conditions. Therefore, the annual collective dose equivalent from flights for Korean is 622.1 man-rem (passengers : 0.79 millions) in international air service. On the other hand, the dose equivalent of a passenger at the altitude (altitude : 12,000ft) of domestic air service was estimated to be 17 μrem and the collective dose equivalent was 23 man-rem (passenger: 1.35 millions) per year. But, these values were the too small to be applicable to all Korean people.

The chances of medical exposure and industrial exposure increase according to the development of a country. However, the degree of exposure by these sources could not be estimated because of the lack of data.

2) Internal exposure dose

Internal radiation exposure occurs upon inhalation of radioactive isotopes from the air and intake of radioactive isotopes in foodstuffs. Internal exposure by the radioisotopes deposited in the body can be calculated by the following equation simplified (22).

$$D_i = DF_i \cdot U \cdot Q_i$$

where D_i means internal radiation exposure by the intake of radioisotope i.

DF_i means dose factor for radioisotope i.

U means usage factor for radioisotope i.

Q_i means the concentration of radionuclide i in the media.

By the equation, the value for internal radiation exposure was calculated on the basis of the data reported previously and our data for food consumption rate. Dose factors used in this calculation were quoted from the report of USNRC (22).

As shown in Tables 4 and 5, internal exposure by Cs-137 was found to be 1.14×10^{-2} mrem per year and that by Sr-90 was estimated to be 8.75

Table 4. The Calculation of Dose Equivalent due to the Ingestion of Cs-137 in Various Foodstuffs (Dose Factor : 7.14×10^{-15} mrem/pCi)

Foodstuff	Ingestion Rate (g/day)	Concentration of Cs-137 (pCi/g)				Annual D.E. (mrem/yr)
		Kori	Wolseong	Kyema	Average	
Grain	408.5	2.73×10^{-3}	1.03×10^{-2}	3.58×10^{-3}	5.37×10^{-3}	5.72×10^{-2}
Vegetables	182.8	5.48×10^{-3}	1.03×10^{-2}	9.23×10^{-3}	8.54×10^{-3}	4.07×10^{-2}
Fishes	63.5	1.25×10^{-2}	6.63×10^{-3}	9.23×10^{-3}	9.45×10^{-3}	1.56×10^{-2}
Shells	2.2	3.03×10^{-3}	—	—	3.03×10^{-3}	0.02×10^{-2}
Seaweeds	7.8	—	2.03×10^{-4}	2.00×10^{-3}	1.12×10^{-3}	0.02×10^{-2}
Total	—	—	—	—	—	1.14×10^{-2}

Table 5. The Calculation of Dose Equivalent due to the Ingestion of Sr-90 in Various Foodstuffs (Dose Factor : 1.86×10^{-3} mrem/pCi)

Foodstuff	Ingestion Rate (g/day)	Concentration of Sr-90 (pCi/g)				Annual D.E. (mrem/yr)
		Kori	Wolseong	Kyema	Average	
Milk	27.2	6.23×10^{-3}	—	—	6.23×10^{-3}	0.12
Grain	408.5	8.45×10^{-3}	4.29×10^{-3}	1.49×10^{-2}	9.21×10^{-3}	2.55
Vegetables	182.8	4.02×10^{-2}	1.13×10^{-2}	4.38×10^{-2}	3.17×10^{-2}	3.93
Fishes	63.5	1.13×10^{-2}	1.48×10^{-2}	4.49×10^{-2}	2.52×10^{-2}	1.09
Shells	2.2	1.65×10^{-3}	—	—	1.65×10^{-3}	2.50×10^{-3}
Seaweeds	7.8	—	1.77×10^{-2}	4.24×10^{-2}	3.01×10^{-2}	0.16
Total	—	—	—	—	—	7.85

mrem per year. But, the intake of other radionuclides may contribute to internal radiation exposure.

REFEREMCES

1) International Commission on Radiological Protection, Report of Committee II on Permissible Dose for Internal Radiation (1959).
2) International Commission on Radiological Protection, Reference Man (1975).
3) Tanaka, G. and A. Tomikawa, Japan Atom. Energy Soc., **19**, 674(1977).
4) Korea Advanced Institute of Science and Technology, BSG 379 : 1441~7 (1980).
5) Normal Data Editing Committee, Normal Biological and Morbidity Data of the Korea, Dongmoonsa (1978).
6) Costeff, H., Arch. Dis. Child., **41**, 681(1966).
7) Ryoo, J.Y., Y.H. Park and K.K. Kim, Report of National Institute of Public Health **1**, 129 (1964).
8) Tanaka, G. and H. Kawamura, Health Phys., **36**(1979).
9) Hong, J.E., J. Korean Med. Soc., **16**, 202(1973).
10) Du Bois, E.F. and D. Du Bois, Arch. Int. Med., **17**, 863(1916).
11) 玄海原子力硏究所周邊環境放射能調査結果, 九州電力株式會社, 日本(1979).
12) 原子力發電所周邊環境放射能調査, 福井縣環境放射能調査會議, 日本(1975).
13) Weng, P.S., C.M. Hsu and H.T. Chang, Environmental Radioactivity survey for Nuclear Power Plants in North Taiwan, NIHU HPS. Report 4, Taiwan (1974).
14) 國民榮養の現狀, 厚生省公衆衛生局, 日本(1979).
15) UNSCEAR, Report of the United Nations Scientific Committee on the Effect of Atomic Radiation. 7th session Supplement No. 16(A/5216), United Nations, NY (1962).
16) Oakley, O.T., Natural Radiation Exposure in the United States, USEPA, PB 235 795(1972).
17) Millikan, R.A. and H.V. Neher, Phys. Res., **50**, 15(1936).
18) Lowder, W.M. and L.R. Solon, USAEC Report NYO-4712 (1956).
19) 國立地質調査所, 地球物理探査報告, 6卷, 韓國 (1972).
20) Cardinale, A. G. Cortellessa, F. Gera, O. Ilari and G. Lembo USAEC Report CONF- 720805-PI (1972).
21) UNSCEAR, Source and Effects of Ionizing Radiation (1977 Report), United Nations, NY (1977).
22) USNRC, Regulatory Guide **1**, 109(1977).
23) Eichholz, G.G., Environmental Aspects of Nuclear Power. Ann Arbor Science, Mich (1976).

標準韓國人의 最大許容 被曝線量 設定에 관한 研究

—體位 및 內·外部 被曝線量 推定—

要　約

標準韓國人의 體位와 內·外部 被曝線量을 推定하기 위하여 韓國人의 身長, 體重, 體表面積을 包含한 體位와 飮食物攝取量 放射能物質攝取量 그리고 環境放射能에 의한 被曝線量을 調査分析하여 다음과 같은 結論을 얻었다.

1) 標準韓國人의 年齡群은 男女 모두 20~30歲이며 男子에 있어서의 身長은 167cm, 體重은 61kg, 體表面積은 1.67m^2이다. 그리고 女子에 있어서의 身長은 155cm, 體重은 51kg, 體表面積은 1.51m^2이다.

2) 韓國人 成人은 1人 1日 812.8g(植物性 669.6g, 動物性 143.2g)의 飮食物을 攝取한다.

3) 韓國人 成人은 飮食物을 通하여 1人 1日 約 1,200pCi(β-線)의 放射能物質을 攝取한다.

4) 韓國人 成人은 年間 127mrem의 外部被曝과, 8mrem의 內部被曝으로 約 135mrem의 環境放放線에 被曝되는 것으로 推算되나 이 線量値는 앞으로 더 많은 資料가 補完됨에 따라 修正된다고 본다.