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Estimation of annual effective dose from ingestion of ^{40}K and ^{137}Cs in foods frequently consumed in Korea

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Abstract The activity concentrations of natural (^{40}K) and anthropogenic (^{137}Cs) radionuclides were measured in the 30 most commonly consumed foods in Korea. The average activity-concentrations of ^{40}K and ^{137}Cs were 67 Bq kg^{-1} and 46 mBq kg^{-1} fresh weight of food, respectively. The total annual intakes of ^{40}K and ^{137}Cs by humans were 14915 and 3.64 Bq year^{-1}, respectively. The calculated mean annual effective doses from ingestion of the investigated foodstuffs were 92 μSv for ^{40}K and 0.047 μSv for ^{137}Cs. Our results can provide useful background information on radiation protection in Korea, and in other countries as well.

Keywords Korean food · Estimation radioactivity · ^{40}K · ^{137}Cs · Effective dose · Dietary intake

Introduction

Radioactivity in the environment originates from natural, terrestrial, extraterrestrial, and anthropogenic sources. Human beings are exposed to radiation internally by ingestion and inhalation of radioactive particles. Dietary intake is considered one of the main pathways of radionuclides into the human body. The average worldwide annual effective dose per capita resulting from external and internal exposure is 2.4 mSv, of which a considerable part (0.3 mSv) is from ingestion of foods and drinking water containing natural radionuclides, such as ^{40}K, ^{238}U, ^{232}Th, and their daughters [1]. The annual effective dose by ingestion of ^{40}K in food contributes ~60 % (0.17 mSv) of total exposure (0.29 mSv) due to the intake of foods [1]. Potassium is one of the most abundant elements (~2.6 % of the weight of the Earth's crust) and is usually contained in the food and water that we consume. There are three isotopes of naturally occurring potassium, with abundances of ^{39}K at 93.3 %, ^{40}K at 0.0117 %, and ^{41}K at 6.73 % [2]. Because potassium is an essential nutrient for human health, a considerable portion (~0.2 %) of the human body mass is K, and the average ^{40}K activity in the body is approximately 4.4 kBq [3].

Atmospheric nuclear weapon tests in the period of 1945–1963, nuclear accidents, the normal operation of nuclear power plants, and recycling of spent nuclear fuel are significant sources of anthropogenic radionuclides in the environment [1, 4]. The main source of ^{137}Cs in Korea, located in western North Pacific, is originated from fallout from atmospheric nuclear weapon test [5]. Although several nuclear facilities have been operated in Korea, the effects to the radiological environment from those facilities can be considered as insignificance. These radionuclides are eventually accumulated in plants and animals and may influence humans directly or indirectly [6]. Among the anthropogenic radionuclides, ^{137}Cs has relatively long half-life (30.17 year). Because ^{137}Cs shows similar chemical and metabolic characteristics as potassium, ^{137}Cs can be accumulated in human muscle tissues by ingestion of foodstuffs [7].

For these reasons, studies have been conducted in many regions to determine the concentration of natural and artificial radionuclides in food and to estimate the effective dose from ingestion of food containing radionuclides

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[8–12]. The internal dose from naturally occurring radionuclides in several Korean foods has been reported [13]. However, there are only a few results available regarding the effective dose from ingestion of ^{40}K and ^{137}Cs in foods [14–18]. Moreover, the results of concentration of radionuclides and internal dosage by intake of some favorite types of Korean food, such as kimchi, rice cake, and tofu have not been reported. The aims of this study are to evaluate the annual dietary intake of ^{40}K and ^{137}Cs in 30 kinds of foods frequently consumed in Korea and to estimate the annual effective dose from these radionuclides.

Materials and methods

Sampling

The sampling and radioactivity of artificial and natural radionuclides in Korean foods have been performed from 1999 to 2012 by the Korea Institute of Nuclear Safety (KINS) (Table 1). The specific activity data presented in this paper were collected from the environmental radioactivity survey results reported by KINS. Among the 30 types of frequently consumed foods in Table 1, 23 kinds of food samples were purchased from local markets in the vicinity of 13 major cities in South Korea, and then were immediately analyzed for determination of specific activities. Since the seven kinds of food samples (beer, soju, beef soup, cola, rice wine, fruit drink, and soymilk) were not collected for radioactivity measurement during the environmental radioactivity survey by KINS, the ^{40}K activity concentrations of seven foods were estimated using the elemental concentration of potassium in foodstuffs from statistics reported by the National Rural Living Science Institute [19].

Determination of ^{40}K and ^{137}Cs activity concentrations

The collected samples were washed with deionized water and dried in electric oven at approximately 90 °C for 1 day after measuring the weight. The dried samples were ashed in muffle furnace at 450 °C to reduce the sample volume and remove organic matter. The ashed samples were transfer to the cylindrical plastic vial for measurement with high-purity germanium (HPGe) detector. For determination of ^{40}K and ^{137}Cs activity concentrations in foodstuffs, an HPGe detector with relative efficiency of 30 % was used. The detection efficiency of the detector was calibrated with the varied sample heights of 0.2–5 cm using a certified standard mixed gamma source. The gamma-ray energies of 1460.75 and 661.62 keV were used to measure the activity concentration of ^{40}K and ^{137}Cs, respectively. The specific activity of ^{40}K in food (A_s), not collected for radioactivity measurement, was defined by the following equation:

$$A_s = C_k \times A \quad (1)$$

$$A = (\mathrm{Na} \times a \times \ln 2) / (100 \times \mathrm{MW} \times T_{1/2}) \quad (2)$$

where A_s is the specific activity of ^{40}K in food (Bq kg^{-1}), C_k is concentration of potassium in food (g kg^{-1}), A is specific activity of potassium (Bq g^{-1} K), Na is Avogadro's constant (6.02×10^{23} mol^{-1}), a is isotopic abundance of ^{40}K (0.0117 %), MW is molecular weight of potassium (39.1 g mol^{-1}), and $T_{1/2}$ is half-life of ^{40}K (4.037×10^{16} s).

The minimum detectable activity (MDA) values were calculated with Genie2k software program (Canberra Industries Inc.). When the radionuclides were not found considerably above the background level in the spectra after measurement, the analysis results were presented in below MDA. The various MDA values in this study could be caused by the different constituents such as measuring times, sample amounts, and detection efficiency.

Calculation of effective dose from foods

The annual effective dose from radionuclides in foodstuffs was calculated using the following equation:

$$D = D_f \times U \times A_s \quad (3)$$

where D denotes the annual effective dose (μSv year^{-1}); D_f is the dose conversion coefficient (μSv Bq^{-1}); U is the amount of foodstuff consumed in 1 year (kg year^{-1}) [20]; A_s is specific activity of ^{40}K by radioactivity measurement or calculation (Eq. 1) using statistics data [19]. The dose conversion coefficients used for ^{40}K and ^{137}Cs were 6.2×10^{-9} and 1.3×10^{-8} Sv Bq^{-1}, respectively [21].

Results and discussion

Activity concentrations of ^{40}K and ^{137}Cs in foods frequently consumed in Korea

The specific activities of ^{40}K and ^{137}Cs measured in each type of food are summarized in Table 2. The specific activity units are Bq kg^{-1} and mBq kg^{-1} for ^{40}K and ^{137}Cs, respectively. Although some food samples, such as green tea and wakame (a kelp species) had already been dried when they were purchased, these samples were regarded as fresh. While ^{40}K in all collected food samples showed specific activities above MDA, ^{137}Cs was only measured above MDA values in 11 food types. Specific

Table 1 Average food consumption rates in Korea and information about food samples used in this work

Food type	Daily intake (g/day)[a]	Intake rate (%)[a]	Number of samples	Sampling time
Rice	169.8	11.6	13 (1)	2012
Milk	75.3	5.2	12 (2)	2012
Kimchi	60.7	4.2	12	2007
Beer	51.2	3.5	–	–
Pork	39.8	2.7	12 (8)	2007
Soju	36.8	2.5	–	–
Mandarin	29.7	2.0	10 (10)	2001
Onion	27.3	1.9	10	2001
Beef soup	26.2	1.8	–	–
Egg	25.2	1.7	20 (1)	1999
Cola	24.7	1.7	–	–
Apple	24.6	1.7	10	2001
Chicken	24.5	1.7	13 (11)	1999, 2008
Chili	24.5	1.7	10	2001
Tomato	21.8	1.5	2	2007
Beef	21.4	1.5	9 (7)	2008
Potato	19.3	1.3	10	2001
Watermelon	19.1	1.3	1	2006
Rice wine	18.9	1.3	–	–
Tofu	18.5	1.3	12	2007
Bread	18.2	1.3	12	2007
Green tea	17.2	1.2	12 (12)	2003
Cucumber	16.0	1.1	12 (1)	2005
Persimmon	15.7	1.1	10 (1)	2001
Grape	14.5	1.0	10	2001
Ramen	13.9	1.0	12	2007
Fruit drink	13.8	1.0	–	–
Rice cake	12.5	0.9	12 (4)	2007
Wakame	12.0	0.8	10	2007–2008, 2011–2013
Soymilk	11.8	0.8	–	–

[a] Data were collected from the Korea Centers for Disease Control & Prevention [20]. Figures in parentheses refer to the number of ^{137}Cs samples

activities of ^{40}K ranged from 0 (cola) to 589 (green tea) Bq kg^{-1} fresh weight of food. Average ^{40}K activity for all types of food was 67 Bq kg^{-1} fresh weight. The activity concentration of ^{40}K in rice (26 Bq kg^{-1}), the most widely consumed food in Korea, was comparable to that (21 Bq kg^{-1}) already measured in Japan [22], and relatively lower than measured elsewhere (Kuwait: 33–101 Bq kg^{-1}; Malaysia: 50–98 Bq kg^{-1}; and India: 121 Bq kg^{-1}) [23–25]. Thus, the activity concentrations of ^{40}K in rice appear to be associated with transfer factors depending on factors such as characteristics of rice varieties and soil environment [26]. Specific activities of ^{40}K in milk (43 Bq kg^{-1}), the second most consumed foodstuff in Korea, were similar to the ranges reported in Japan (50 Bq kg^{-1}) [22] and India (34 Bq kg^{-1}) [27]. In this study, the activity concentrations of ^{40}K in kimchi (85 Bq kg^{-1}), the third most consumed food and one of the most popular traditional foods in Korea, were similar to those in pork, tomatoes, and beef. Activity concentrations of ^{40}K in green tea (465 Bq kg^{-1}), the highest activity in the 30 most commonly consumed foods in Korea, were similar to that (450 Bq kg^{-1}) reported in Turkey [28]. In general, potassium is a large portion of the ingredients in green tea leaves [29].

The specific activities of ^{137}Cs were estimated to be less than MDA in 12 food types (kimchi, onions, apples, chili, tomatoes, potatoes, watermelon, tofu, bread, grapes, ramen, and wakame) investigated in this study (Table 2). Activity concentrations of ^{137}Cs in seven food samples (beer, soju, beef soup, cola, rice wine, fruit drink, and soymilk) were not measured in this study. Specific activities of ^{137}Cs ranged from less than MDA to 606 (beef) mBq kg^{-1} fresh

Table 2 Average specific activities of ^{40}K and ^{137}Cs in foods frequently consumed in Korea

Food type	^{40}K (Bq kg^{-1}) Mean ± SD (range)	^{137}Cs (mBq kg^{-1}) Mean ± SD (range)
Rice	26 ± 12 (15–64)	11
Milk	43 ± 8 (18–48)	23 ± 1 (23–24)
Kimchi	85 ± 16 (64–110)	<MDA (22–45)
Beer	7	–
Pork	85 ± 34 (48–178)	32 ± 16 (15–61)
Soju	0	–
Mandarin	43 ± 10 (31–59)	26 ± 14 (12–57)
Onion	43 ± 10 (29–62)	<MDA (6–18)
Beef soup	2	–
Egg	38 ± 8 (28–67)	24
Cola	0	–
Apple	44 ± 12 (29–64)	<MDA (5–17)
Chicken	69 ± 16 (44–94)	28 ± 12 (11–53)
Chili	90 ± 18 (68–123)	<MDA (8–39)
Tomato	89 ± 5 (85–92)	<MDA (17–19)
Beef	85 ± 24 (41–128)	113 ± 113 (19–606)
Potato	118 ± 13 (96–139)	<MDA (15–26)
Watermelon	47	<MDA (7)
Rice wine	5	–
Tofu	43 ± 9 (31–63)	<MDA (11–27)
Bread	33 ± 9 (22–51)	<MDA (11–24)
Green tea	465 ± 125 (212–589)	185 ± 84 (76–372)
Cucumber	52 ± 8 (39–65)	10
Persimmon	47 ± 7 (33–59)	11
Grape	65 ± 14 (48–88)	<MDA (7–30)
Ramen	60 ± 13 (27–79)	<MDA (15–60)
Fruit drink	131	–
Rice cake	24 ± 23 (5–66)	22 ± 13 (12–41)
Wakame	153 ± 35 (101–204)	<MDA (41–104)
Soymilk	3	–

MDA minimum detectable activity

weight of food. Average ^{137}Cs activity concentration for all types of food was 46 mBq kg^{-1} fresh weight. The average value of ^{137}Cs in the foods commonly consumed in Korea was three orders of magnitude lower than that of ^{40}K. These results are consistent with those reported in Kuwait [23] and Egypt [30]. Activity concentrations of ^{137}Cs in meat (113 mBq kg^{-1} for beef, 32 mBq kg^{-1} for pork, and 28 mBq kg^{-1} for chicken) in Korea were relatively higher than those in meat (53 mBq kg^{-1}) in Japan [17]. However, activity concentrations of ^{137}Cs in green tea (185 mBq kg^{-1}), in rice (11 mBq kg^{-1}), and in cucumbers (10 mBq kg^{-1}) in Korea were relatively lower than those in green tea (900 mBq kg^{-1}) in Egypt [31], in rice (100 mBq kg^{-1}) in Kuwait [23], and in cucumber (20–310 mBq kg^{-1}) in Egypt [30]. The activity concentration of ^{137}Cs in milk in Korea was similar to that (30 mBq kg^{-1}) in Lithuania [16].

Annual intakes of ^{40}K and ^{137}Cs in foods frequently consumed in Korea

In order to calculate annual intakes of ^{40}K and ^{137}Cs, the average activity concentrations of ^{40}K and ^{137}Cs were multiplied by the consumption rate of foods determined by the Korean Ministry of Health and Welfare [32, 33]. The estimated annual intakes of ^{40}K and ^{137}Cs in frequently consumed foods in Korea are presented in Table 3. The annual intakes in Korean foods ranged from 0 (soju and cola) to 1883 Bq year^{-1} (kimchi) for ^{40}K, and from 0.02 (green tea) to 0.88 Bq year^{-1} (beef) for ^{137}Cs. The total annual intake of ^{40}K (14,915 Bq year^{-1}) was much higher than that of ^{137}Cs (3.64 Bq year^{-1}).

The ranking of the annual intake sources of ^{40}K were kimchi > rice > pork > milk > potato > chili in Korean foods, and intakes were relatively higher in these foods. The high annual intakes of ^{40}K in kimchi, rice, pork, and milk seem to be due to high food consumption rates in Korea, but those in potato and chili appear to be associated with high ^{40}K activity. The total annual intake of ^{40}K in foods frequently consumed in Korea in this study was similar to that (14,381 Bq year^{-1}) previously reported in Korea [13] but was lower than that reported in the Pakistan (29,178 Bq year^{-1}) [15], China (22,886 Bq year^{-1}) [34], and India (21,367 Bq year^{-1}) [35].

The ranking of annual intake sources of ^{137}Cs were beef > rice > milk > pork in Korean foods, and intakes were relatively higher in beef, rice, milk, and pork than in other foods (mandarin, egg, chicken, green tea, cucumber, persimmon, and rice cake). The high annual intakes of ^{137}Cs in rice, milk, and pork seem to be due to high food consumption rates in Korea. In particular, the highest annual intake of ^{137}Cs in beef appears to be associated with environmental concentrations (i.e. biomagnifications) depending on higher trophic levels. In this context, the annual intake of ^{137}Cs in meat, such as beef and pork, was relatively higher than in vegetables and fruits. The total annual intake of ^{137}Cs in foods frequently consumed in Korea in this study was lower than that reported in Ukraine (1478 Bq year^{-1}) [36], in Taiwan (60 Bq year^{-1}) [14], and in Japan (23 Bq year^{-1}) [37].

Annual intakes of ^{40}K showed significantly positive correlations with annual intakes of ^{137}Cs (Fig. 1). This result indicated that the annual intakes of ^{40}K and ^{137}Cs have the same ordering for most of foodstuffs. Although ^{40}K and ^{137}Cs exhibited similar behavior in foods due to the chemical characteristics of the alkali group in the periodic table, the highest annual intakes of ^{40}K and ^{137}Cs were different in the consumed foods in Korea. The annual

Table 3 Annual intakes and internal dose of ^{40}K and ^{137}Cs from ingestion of foods

Food type	^{40}K		^{137}Cs	
	Annual intake (Bq year^{-1})	Internal dose (μSv year^{-1})	Annual intake (Bq year^{-1})	Internal dose (nSv year^{-1})
Rice	1611	10	0.68	8.9
Milk	1182	7.3	0.63	8.2
Kimchi	1883	12	–	–
Beer	131	0.8	–	–
Pork	1235	7.7	0.46	6.0
Soju	0	0	–	–
Mandarin	466	2.9	0.28	3.7
Onion	428	2.7	–	–
Beef soup	19	0.1	–	–
Egg	350	2.2	0.22	2.9
Cola	0	0	–	–
Apple	395	2.4	–	–
Chicken	617	3.8	0.24	3.1
Chili	805	5.0	–	–
Tomato	708	4.4	–	–
Beef	664	4.1	0.88	11
Potato	831	5.2	–	–
Watermelon	328	2.0	–	–
Rice wine	34	0.2	–	–
Tofu	290	1.8	–	–
Bread	219	1.4	–	–
Green tea	44	0.3	0.02	0.2
Cucumber	304	1.9	0.06	0.8
Persimmon	269	1.7	0.06	0.8
Grape	344	2.1	–	–
Ramen	304	1.9	–	–
Fruit drink	660	4.1	–	–
Rice cake	110	0.7	0.10	1.3
Wakame	670	4.2	–	–
Soymilk	13	0.1	–	–
Total	14,915	92	3.64	47

intakes of ^{40}K appear to be associated with food consumption rates and the specific activities of ^{40}K in foods, while those of ^{137}Cs seem to be closely linked to bioaccumulation as well as food consumption rates.

Annual effective dose

The annual effective doses from intake of ^{40}K and ^{137}Cs in foodstuffs were calculated from the average activity concentrations of ^{40}K and ^{137}Cs, the annual consumption of typical Korean foods [32], and the dose conversion coefficients used for ^{40}K and ^{137}Cs. The estimated annual effective doses of ^{40}K and ^{137}Cs from ingestion of Korean foods are presented in Table 3. The annual effective doses from ingestion of Korean foods were ranged from 0 (soju and cola) to 12 μSv year^{-1} (kimchi) for ^{40}K and from 0.2 (green tea) to 11 nSv year^{-1} (beef) for ^{137}Cs. The total annual effective dose of ^{40}K (92 μSv year^{-1}) was much higher than that of ^{137}Cs (47 nSv year^{-1}). These results track the trends of the annual intake of ^{40}K and ^{137}Cs.

The total annual effective dose of ^{40}K in foods mainly consumed in Korea in this study was lower than that reported in Iran (5240 μSv year^{-1}) [18] in Pakistan (165 μSv year^{-1}) [15], and in Japan (130–217 μSv year^{-1}) [17]. The total annual effective dose of ^{137}Cs in foods mainly consumed in Korea in this study was lower than that

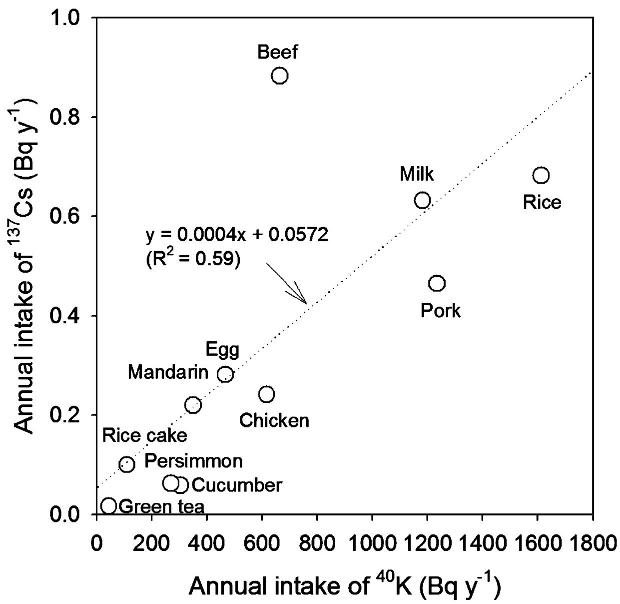

Fig. 1 Annual intake of ^{40}K versus annual intake of ^{137}Cs in foods of Korea

reported in Iran (2490 nSv year^{-1}) [18], in Taiwan (780 nSv year^{-1}) [14], and in Japan (49–378 nSv year^{-1}) [17].

Conclusions

This study estimated the specific activities of ^{40}K and ^{137}Cs in the 30 most commonly consumed foods in Korea. The highest activity concentration of ^{40}K and ^{137}Cs and the highest annual intake of ^{40}K and ^{137}Cs in foodstuffs frequently consumed in Korea showed in green tea and beef and kimchi and beef, respectively. The annual intake and annual effective dose of ^{40}K were much higher than those of ^{137}Cs. Because the chemical and metabolic characteristics of potassium and cesium are similar, the distributions of ^{40}K and ^{137}Cs in the most frequently consumed foodstuffs in Korea show similar trends. More extensive studies are necessary to elucidate the effects of ^{40}K and ^{137}Cs in the human body after their ingestion in foods.

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References

1. United Nation Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (2000) Sources and effects of ionizing radiation (2000) In: UNSCEAR 2000 Report, Annex B: Exposures from Natural Radiation Sources. United Nations, New York
2. Berglund M, Wieser ME (2011) Isotopic compositions of the elements 2009 (IUPAC Technical Report). Pure Appl Chem 83(2):397–410
3. Tykva R, Sabol J (1995) Low-level environmental radioactivity sources and evaluation. Technomic Publishing Company Inc, Lancaster
4. International Atomic Energy Agency (IAEA) (2006) Applicability of monitored natural attenuation at radioactively contaminated sites. Technical Reports Series, Vienna, p 445
5. Povinec PP, Aoyama M, Biddulph D, Breier R, Buesseler K, Chang CC, Golser R, Hou XL, Ješkovský M, Jull AJT, Kaizer J, Nakano M, Nies H, Palcsu L, Papp L, Pham MK, Steier P, Zhang LY (2013) Cesium, iodine and tritium in NW Pacific waters—a comparison of the Fukushima impact with global fallout. Biogeosciences 10:5481–5496
6. Rachubik J, Grosicki A (2009) Radiocaesium activity concentrations in Polish food of animal origin and radiation dose assessment for consumers. Bull Vet Inst Pulawy 53:839–843
7. Bhat R, Gómez-López VM (2014) In: Bhat R, Gómez-López VM (eds) Practical food safety: contemporary issues and future directions. Wiley, New York
8. Hernández F, Hernández-Armas J, Catalán A, Fernández-Aldecoa JC, Landeras MI (2004) Activity concentrations and mean annual effective dose of foodstuffs on the island of Tenerife, Spain. Radiat Prot Dosim 111(2):205–210
9. Jibiri NN, Farai IP, Alausa SK (2007) Estimation of annual effective dose due to natural radioactive elements in ingestion of foodstuffs in tin mining area of Jos-Plateau, Nigeria. J Environ Radioact 94:31–40
10. Landstetter C, Zapletal M, Sinojmeri M, Katzlberger C (2013) Measurements of natural and artificial radionuclides in food samples and water for human consumption in Austria for the calculation of the ingestion dose. J Radioanal Nucl Chem 296:905–908
11. Patra AC, Mohapatra S, Sahoo SK, Lenka P, Dubey JS, Thakur VK, Kumar AV, Ravi PM, Tripathi RM (2014) Assessment of ingestion dose due to radioactivity in selected food matrices and water near Vizag, India. J Radioanal Nucl Chem 300:903–910
12. Tufail M, Sabiha-Javied Akhtar N, Akhter J (2010) Assessment of annual effective dose from natural radioactivity intake through wheat grain produced in Faisalabad, Pakistan. J Radioanal Nucl Chem 283:585–590
13. Choi MS, Lin XJ, Lee SA, Kim W, Kang HD, Doh SH, Kim DS, Lee DM (2008) Daily intakes of naturally occurring radioisotopes in typical Korean foods. J Environ Radioact 99:1319–1323
14. Wang CJ, Lai SY, Huang CC, Lin YM (1996) Annual intake of ^{137}Cs and ^{90}Sr from ingestion of main foodstuffs in Taiwan. J Health Phys 31(2):185–191
15. Akhter P, Ashraf N, Mohammad D, Orfi SD, Ahmad N (2003) Nutritional and radiological impact of dietary potassium on the Pakistani population. Food Chem Toxicol 41:531–534
16. Butkus D, Laučytė I, Ladygienė R (2006) Estimation of effective dose caused by ^{40}K, ^{90}Sr and ^{137}Cs in daily food. J Environ Eng Landsc 2:77–81
17. Sugiyama H, Terada H, Takahashi M, Iijima I, Isomura K (2007) Contents and daily intakes of gamma-ray emitting nuclides, ^{90}Sr, and ^{238}U using market-basket studies in Japan. J Health Sci 53(1):107–118
18. Changizi V, Jafarpoor Z, Naseri M (2010) Measurement of ^{226}Ra, ^{228}Ra, ^{137}Cs and ^{40}K in edible parts of two types of leafy vegetables cultivated in Tehran province-Iran and resultant annual ingestion radiation dose. Iran J Radiat Res 8(2):103–110
19. National Rural Living Science Institute (2001) Food composition table. Sixth revision, Suwon
20. Korea Centers for Disease Control & Prevention (2012) Korea Health Statistics 2012: Korea National Health and Nutrition Examination Survey (KNHANES V-3)

21. International Committee of Radiological Protection (1996) Age dependent doses to members of public from intake of radionuclides: compliation of ingestion and inhalation coefficients. ICRP Publication, Ottawa, p 72
22. Shiraishi K (2005) Dietary intakes of eighteen elements and ^{40}K in eighteen food categories by Japanese subjects. J Radioanal Nucl Chem 266(1):61–69
23. Alrefae T, Nageswaran TN (2013) Radioactivity of long lived gamma emitters in rice consumed in Kuwait. J Assoc Arab Univ Basic App Sci 13(1):24–27
24. Asaduzzaman Kh, Khandaker MU, Amin YM, Mahat R (2015) Uptake and distribution of natural radioactivity in rice from soil in north and west part of peninsular Malaysia for the estimation of ingestion dose to man. Ann Nucl Energy 76:85–93
25. Shanthi G, Maniyan CG, Allan Gnana Raj G, Thampi Thanka Kumaran J (2009) Radioactivity in food crops from high background radiation area in southwest India. Curr Sci 97(9):1331–1335
26. Coughtrey PJ, Thorne MC (1983) Radionuclide distribution and transport in terrestrial and aquatic ecosystems: a critical review of data, vol 1. Balkema, Rotterdam
27. Shanthi G, Thmpi Thanka Kumaran J, Allan Gnana Raj G, Maniyan CG (2010) Natural radionuclides in the South Indian foods and their annual dose. Nucl Instrum Methods Phys Res A 619:436–440
28. Görür FK, Keser R, Akçay N, Dizman S, Okumusoglu NT (2011) Radionuclides and heavy metals concentrations in Turkish market tea. Food Control 22:2065–2070
29. Venkatesan S, Murugesan S, Senthur Pandian VK, Ganapathy MNK (2005) Impact of sources and doses of potassium on biochemical and greenleaf parameters of tea. Food Chem 90:535–539
30. Badran HM, Sharshar T, Elnimer T (2003) Levels of ^{137}Cs and ^{40}K in edible parts of some vegetables consumed in Egypt. J Environ Radioact 67:181–190
31. Harb S (2006) Measurement of the radioactivity of ^{238}U, ^{226}Ra, ^{210}Pb, ^{228}Th, ^{232}Th, ^{228}Ra, ^{137}Cs and ^{40}K in tea using gamma-spectrometry. J Radioanal Nucl Chem 274:63–66
32. Ministry of Health & Welfare of Korea (MOHW) (2002) 2001 National health and nutrition survey. Report on overview, MOHW, Seoul, Korea
33. Ministry of Health & Welfare of Korea (MOHW) (2005) 2004 National health and nutrition survey. Report on overview, MOHW, Seoul, Korea
34. Wang JX, Chen RS, Zhu HD (2000) Studies in China on ingestion and organ content of trace elements of importance in radiological protection. Working paper presented at final RCM-3 of Reference Asian Man Phase 2, Vietnam
35. Dang HS, Jaiswal DD, Nair S, Pullat VR (2000) Some importsant input data for generating population specific biokinetic parameters of a few selected radionuclides encountered in nuclear fuel cycle—application in internal dosimetry. Working paper presented at final RCM-3 of Reference Asian Man Phase 2, Vietnam
36. Shiraishi K, Tagami K, Ban-nai T, Yamamoto M, Muramatsu Y, Los IP, Phedosenko GV, Korzun VN, Tsigankov NY, Shegeda II (1997) Daily intakes of ^{134}Cs, ^{137}Cs, ^{40}K, ^{232}Th and ^{238}U in Ukrainian adult males. Health Phys 73:814–819
37. Fukushima H, Nakayama I (1992) Radioactivity survey of fallout, water, seawater, soil, and food samples in Japan. the 34th proceeding of environmental radioactivity survey. Science and Technology Agency, Tokyo, Japan, pp 39–42