Pergamon

Appl. Radiat. Isot. Vol. 49, Nos 1-2, pp. 29–34, 1998

Printed in Great Britain
PII: S0969-8043(97)00249-2
0969-8043/97 $19.00 + 0.00

Radioactivity Concentrations of ^{137}Cs and ^{40}K in Basidiomycetes Collected in Taiwan

JENG-JONG WANG, CHIH-JUNG WANG, SHU-YING LAI and YU-MING LIN*

Radiation Monitoring Center, Atomic Energy Council, 823 Cherng Ching Road, Kaohsiung, 833, Taiwan, R.O.C.

(Received 13 March 1997; in revised form 24 April 1997)

Radioactivity concentrations of ^{137}Cs and ^{40}K in 64 mushroom samples belonging to 16 species of basidiomycetes collected at various locations in Taiwan have been measured in 1994. All of the samples were mushrooms cultivated indoors. The concentrations of ^{137}Cs in many samples were below the limit of detection (< 1.0 Bq kg^{-1} dry weight), and ^{134}Cs was not detected in any of the samples. The radioactivity concentration ranges of ^{137}Cs and ^{40}K in basidiomycetes were < 1.0–7.3 Bq kg^{-1} dry weight and < 50–1230 Bq kg^{-1} dry weight, respectively. The transfer factors of *F. velutipes*, *G. lucidum* and *L. edodes* from sawdust (growing substrate) to mushroom were ~10, 10.2, < 3.8 for ^{137}Cs, and 7.2, 1.6, 1.8 for ^{40}K, respectively. The effective dose equivalent due to the dietary intake of radiocesium through mushrooms for the Taiwanese people was estimated to be only 4.4×10^{-10} Sv y^{-1}.

Introduction

About 100,000 species of fungi are currently recognized, and probably thousands more species are still undiscovered (Johnson *et al.*, 1984). All fungi are heterotrophic and absorb nutrients from the organic material on which they grow, being different from higher plants which are autotrophic by photosynthesis. Basidiomycetes is one division of the fungi kingdom. Many basidiomycetes are edible, such as the common field mushroom, *Agaricus campestris*.

Grueter (1971) found that ^{137}Cs from the fallout of nuclear weapons testing was concentrated in mushrooms collected in Germany during 1963–1970; the highest radioactivity recorded was 1133 Bq kg^{-1} (wet weight) in a *Boletus badius* sample. Haselwandter (1978) reported that the accumulation of the radioactive nuclide in the fruitbodies of 12 species of basidiomycetes collected in Austria varied among species to species. Many species of lichen and mushroom samples were collected at various locations in Austria at different times after the Chinese nuclear weapons test on 16 October 1980 (Eckl *et al.*, 1986). They found that, generally, mushrooms took larger amounts of ^{137}Cs and ^{40}K than lichens, and the radioactivity concentrations of ^{137}Cs and ^{40}K for mushrooms depended on the species and its growing substrate. The highest radioactivity concentrations of ^{137}Cs and ^{40}K were 21,296 Bq kg^{-1} (dry weight) and 363 Bq kg^{-1} (dry weight), respectively.

On 26 April 1986 the most serious accident in the history of the nuclear industry occurred at the Chernobyl nuclear power plant in the former Ukrainian Republic of the Union of Soviet Socialist Republics (EC/IAEA/WHO, 1996). A large amount of radioactive material was released to the environment, and the first radioactive fallout in Taiwan was monitored on 7 May 1986 (Lin and Huang, 1988). After the Chernobyl accident, many data reporting on the concentrations of ^{134}Cs and ^{137}Cs in mushrooms were reported (Teherani, 1987, 1988). The data showed that the mushrooms had taken up a large amount of cesium isotope from the rain which was strongly contaminated because of the Chernobyl accident. The mushrooms contained up to 200,000 Bq of radiocesium (^{134}Cs and ^{137}Cs) per kilogram of dry weight (Randa, 1988). Horyna and Randa (1988) also found that the concentration factors of the non-radioactive cesium for mushroom were not significantly different from those for vascular plants, whereas in the case of radioactive cesium the values found were orders of magnitude higher. This difference in behavior of natural and radioactive cesium may be due to their disequilibrium in the ecosystems. Bioconcentrations of ^{137}Cs and ^{40}K were measured in vegetation and in red-backed voles collected in southeastern Manitoba, Canada after the Chernobyl accident (Mihok *et al.*, 1989). The findings suggest that fungi, or the animals that consume them,

*To whom all correspondence should be addressed.

can serve as sensitive indicators of ^{137}Cs contamination in the environment. Recently, concentrations of ^{137}Cs, ^{134}Cs and ^{40}K in about 60 mushroom samples belonging to 25 species collected in Japan have been studied (Muramatsu *et al.*, 1991), and the effective dose equivalent for the Japanese public from the dietary intake of radiocesium through mushrooms was estimated to be 1.6×10^{-7} Sv y^{-1}.

The quantities of cultural production of mushrooms in Taiwan used to be the greatest in the world.

Table 1. Radioactivity concentrations of ^{137}Cs and ^{40}K (Bq kg^{-1}) in basidiomycetes collected in Taiwan (dry weight basis)

Code	Species	Location	^{137}Cs	^{40}K	$^{137}Cs/^{40}K$
AA-TC	*Agracybe aegerita*	Taichung	—	1160 ± 46	
AB-TC	*Agaricus bitorquis*	Taichung	—	—	
AB-KH	*Agaricus bitorquis*	Kaohsiung	—	93 ± 7	
AF-CY1	*Auricularia fuscosuccinia*	Chiayi	—	340 ± 20	
AF-CY2	*Auricularia fuscosuccinia*	Chiayi	—	400 ± 28	
AP-CY1	*Auricularia polytricha*	Chiayi	1.3 ± 0.2	290 ± 14	4.5×10^{-3}
AP-CY2	*Auricularia polytricha*	Chiayi	—	300 ± 15	
AP-CY3	*Auricularia polytricha*	Chiayi	—	380 ± 23	
AP-CY4	*Auricularia polytricha*	Chiayi	—	410 ± 17	
AP-CY5	*Auricularia polytricha*	Chiayi	—	340 ± 20	
AP-CH	*Auricularia polytricha*	Changhua	2.1 ± 0.3	330 ± 16	6.3×10^{-3}
AP-TN	*Auricularia polytricha*	Tainan	—	180 ± 14	
CV-NT	*Coriolus versicolor*	Nantou	1.2 ± 0.2	187 ± 9	6.6×10^{-3}
FV-TC1	*Flamulina velutipes*	Taichung	—	1040 ± 42	
FV-TC2	*Flamulina velutipes*	Taichung	—	1090 ± 44	
FV-TC3	*Flamulina velutipes*	Taichung	—	1230 ± 49	
FV-TC4	*Flamulina velutipes*	Taichung	—	1030 ± 31	
FV-ML	*Flamulina velutipes*	Miali	—	1010 ± 30	
FV-PT	*Flamulina velutipes*	Pintung	—	1010 ± 40	
GL-NT1	*Ganoderma lucidum*	Nantou	1.7 ± 0.3	132 ± 9	1.3×10^{-2}
GL-NT2	*Ganoderma lucidum*	Nantou	1.4 ± 0.2	240 ± 12	5.8×10^{-3}
GL-NT3	*Ganoderma lucidum*	Nantou	1.1 ± 0.2	103 ± 8	1.1×10^{-2}
GL-TY	*Ganoderma lucidum*	Tauyan	1.1 ± 0.2	129 ± 9	8.8×10^{-3}
GS-NT	*Ganoderma sp.*	Nantou	—	170 ± 15	
GT-CY	*Ganoderma tsuga*	Chiayi	7.3 ± 0.4	160 ± 10	4.5×10^{-2}
GT-TC	*Ganoderma tsuga*	Tsinchu	—	190 ± 11	
GF-TC	*Grifora frondosa*	Taichung	—	650 ± 33	
HE-CH	*Hericium erinaceus*	Chunghua	—	910 ± 36	
LE-CH1	*Lentinula edodes*	Chunghua	4.2 ± 0.9	430 ± 39	9.9×10^{-3}
LE-CH2	*Lentinula edodes*	Chunghua	—	540 ± 27	
LE-IL1	*Lentinula edodes*	Ilan	—	610 ± 37	
LE-IL2	*Lentinula edodes*	Ilan	3.6 ± 0.9	440 ± 35	8.0×10^{-3}
LE-NT1	*Lentinula edodes*	Nantou	—	740 ± 30	
LE-NT2	*Lentinula edodes*	Nantou	—	420 ± 38	
LE-TC1	*Lentinula edodes*	Taichung	—	580 ± 35	
LE-TC2	*Lentinula edodes*	Taichung	—	580 ± 35	
LE-TC3	*Lentinula edodes*	Taichung	—	450 ± 13	
LE-TC4	*Lentinula edodes*	Taichung	—	370 ± 33	
LE-TC5	*Lentinula edodes*	Taichung	—	510 ± 46	
LE-TC6	*Lentinula edodes*	Taichung	—	510 ± 35	
LE-TC7	*Lentinula edodes*	Taichung	—	660 ± 46	
LE-TC8	*Lentinula edodes*	Taichung	—	560 ± 39	
LE-TC9	*Lentinula edodes*	Taichung	1.3 ± 0.3	80 ± 16	1.6×10^{-2}
LE-TSC1	*Lentinula edodes*	Tsinchu	—	480 ± 24	
LE-TSC2	*Lentinula edodes*	Tsinchu	—	460 ± 32	
LE-TSC3	*Lentinula edodes*	Tsinchu	—	440 ± 36	
LE-TSC4	*Lentinula edodes*	Tsinchu	—	530 ± 27	
LE-TSC5	*Lentinula edodes*	Tsinchu	—	640 ± 32	
LE-TSC6	*Lentinula edodes*	Tsinchu	—	480 ± 19	
LE-TSC7	*Lentinula edodes*	Tsinchu	2.8 ± 0.6	800 ± 32	3.4×10^{-3}
LE-TT1	*Lentinula edodes*	Taitung	—	490 ± 29	
PC-CH1	*Pleuriotus. cystidiosus*	Chunghua	—	1010 ± 50	
PC-CH2	*Pleuriotus. cystidiosus*	Chunghua	—	1000 ± 40	
PC-CY1	*Pleuriotus. cystidiosus*	Chiayi	—	—	
PC-CY2	*Pleuriotus. cystidiosus*	Chiayi	—	830 ± 33	
PC-CY3	*Pleuriotus. cystidiosus*	Chiayi	—	960 ± 48	
PC-CY4	*Pleuriotus. cornucopiae*	Chiayi	—	—	
PC-CY5	*Pleuriotus. sp.*	Chiayi	—	—	
PC-PT	*Pleuriotus. cystidiosus*	Pintung	2.8 ± 0.6	1220 ± 48	2.3×10^{-3}
PC-TC	*Pleuriotus. eryngii*	Taichung	—	1000 ± 50	
POC-CY1	*Poria coccus*	Chiayi	—	70 ± 13	
POC-CY2	*Poria coccus*	Chiayi	—	—	
VV-NT	*Volvariella volvacea*	Nantou	—	—	
VV-KH	*Volvariella volvacea*	Kaohsiung	—	132 ± 8	

1. —: Values which are below the detection limit (1.0 and 50 Bq kg^{-1} for ^{137}Cs and ^{40}K, respectively).
2. All of the mushrooms are cultivated indoors.

Today, Taiwan is still one of the most important exporting countries of mushrooms (Council of Agriculture, Taiwan, 1995). In this research about 64 mushroom samples belonging to 16 species of basidiomycetes and some growing substrate (sawdust) samples were collected at various locations in Taiwan in order to determine the levels of radiocesium and ^{40}K in mushrooms in Taiwan, and the radioactivity concentrations of ^{137}Cs and ^{40}K were measured. We have estimated the effective dose equivalent due to the dietary intake of ^{137}Cs through mushrooms in Taiwan from the ^{137}Cs concentrations in the mushrooms.

Experimental

Sampling and pretreatment

16 species of basidiomycetes and substrate (sawdust) samples were collected at various location in Taiwan in 1994. All the mushroom samples were cultivated indoors, and all mushroom and sawdust samples were purchased from local farmers. All the samples were dried to constant weight at 40–50°C and then ashed below 450°C for 24 h.

Analytical methods

The radioactivity concentrations of ^{137}Cs and ^{40}K in this study were analyzed by gamma-ray spectrometry (The Science and Technology Agency, Japan, 1990). A gamma-ray spectrometry system based on a Ge detector (FWHM 1.82 keV at 1.33 MeV) coupled to a computerized data acquisition system (4096-channel pulse height analyzer) was used to determine the radioactivity concentrations in mushroom and sawdust samples. The ashed samples of the mushrooms and sawdusts were sealed in a cylindrical container. Each sample was placed on the detector, and the measurement was done for 80,000 s. The efficiency calibration was carried out using a standard multi-gamma source mixed with agar which was sealed in a cylindrical container. The limits of detection for ^{137}Cs and ^{40}K were 1.0 and 50 Bq kg^{-1} (dry weight), respectively.

Results and Discussion

Radioactivity concentrations of ^{137}Cs *and* ^{40}K *in mushrooms*

The radioactivity concentrations of ^{137}Cs and ^{40}K in basidiomycetes obtained in this study are shown in Table 1. In most of the samples, concentrations of ^{137}Cs are below the limit of detection (1.0 Bq kg^{-1} dry weight), and no ^{134}Cs was detected in any of the samples. The radioactivity concentration range of ^{137}Cs is <1–7.3 Bq kg^{-1} dry weight, which is not so high as that obtained in Austria (^{137}Cs: 18–3852 Bq kg^{-1} wet weight; and ^{134}Cs: 11–1556 Bq kg^{-1} wet weight) (Teherani, 1987) and

Table 2. Average radioactivity concentrations (Bq kg^{-1}) and transfer factors (TF) of ^{137}Cs and ^{40}K from sawdust to basidiomycetes collected in Taiwan (dry weight basis)[a]

Species	^{137}Cs			^{40}K			^{137}Cs/^{40}K	
	Mushroom	Sawdust	TF	Mushroom	Sawdust	TF	Mushroom	Sawdust
F. velutipes (6)[b]	< 1.0	< 0.10	~10	1070 ± 85	148 ± 9	7.2	$< 9.3 \times 10^{-4}$	$< 6.8 \times 10^{-4}$
G. lucidum (4)	1.3 ± 0.3	0.13 ± 0.02	10.2	150 ± 61	95 ± 1	1.6	8.7×10^{-3}	1.4×10^{-3}
L. edodes (23)	< 1.3	0.34 ± 0.04	< 3.8	540 ± 117	299 ± 3	1.8	$< 2.4 \times 10^{-3}$	1.1×10^{-3}

[a] For the calculation of average concentration, values described as 'limit of detection' were also included.
[b] Number of samples in parentheses.

Japan (^{137}Cs: <3–1520 Bq kg^{-1} dry weight and ^{134}Cs: <1–97 Bq kg^{-1} dry weight) (Muramatsu *et al.*, 1991).

In contrast to the low radioactivity concentrations of ^{137}Cs, the radioactivity concentrations of ^{40}K in basidiomycetes range from <50 to 1230 Bq kg^{-1} dry weight, and the range is in good agreement with that obtained by Muramatsu *et al.* (1991). It is evident that the level of the naturally occurring radionuclide, ^{40}K, fluctuated within a narrow range, and that the concentration of ^{40}K is generally much higher than that of the artificial radionuclides, ^{137}Cs and ^{134}Cs, in basidiomycetes. Because of their chemical similarity, cesium is expected to behave as potassium in the fungi-growing substrate system. As shown in Table 1, the radioactivity concentration ratio of ^{137}Cs vs. ^{40}K ($^{137}Cs/^{40}K$) ranges from 2.3×10^{-3} to 4.5×10^{-2}.

Transfer factors of ^{137}Cs and ^{40}K

For studying the transfer factors for ^{137}Cs and ^{40}K, three species of mushroom and their growing matrix (sawdust) were collected and analyzed. The average radioactivity concentrations and transfer factors (TF) of ^{137}Cs and ^{40}K from sawdust to mushroom are listed in Table 2, together with the concentration ratio $^{137}Cs/^{40}K$. The transfer factors of *F. velutipes*, *G. lucidum* and *L. edodes* from sawdust to mushroom were ~10, 10.2, <3.8 for ^{137}Cs, and 7.2, 1.6, 1.8 for ^{40}K, respectively. The results were in good agreement with those reported by Eckl *et al.* (1986) (^{137}Cs: 0.2–92.7; ^{40}K: 1.5–22.7) and Horyna and Randa (1988) (^{137}Cs: 0.32–99).

Muramatsu *et al.* (1991) reported that the $^{137}Cs/^{40}K$ ratios of *L. hatsudake* (0.26) and *S. granulatus* (0.53) were higher than those of the soils (0.098 and 0.056) in which the mycelium grew. This indicates that these two species and possibly other species with high $^{137}Cs/^{40}K$ ratios have the capacity for the selective uptake of cesium over potassium. As seen in Table 2, the $^{137}Cs/^{40}K$ ratios of *F. velutipes* ($<9.3 \times 10^{-4}$), *G. lucidum* (8.7×10^{-3}) and *L. edodes* ($<2.4 \times 10^{-3}$) are slightly higher than those of sawdusts ($<6.8 \times 10^{-4}$, 1.4×10^{-3} and 1.1×10^{-3}). ^{137}Cs may be in equilibrium with stable cesium in the sawdusts, and for this reason radioactive cesium is similar to potassium in its transfer from the sawdusts to the mushrooms.

Annual effective dose equivalent

The most common edible Taiwanese mushrooms are *Agaricus bitorquis*, *Lentinula edodes*, *Pleuriotus cystidiosus*, *Auricularia polytricha*, *Flamulina velutipes* and *Volvariella volvacea*. The most common edible mushrooms mentioned above are all cultivated indoors using sawdust. Because sawdust is less contaminated with radiocesium than soil, cultivated mushrooms are expected to have lower ^{137}Cs concentrations than wild mushrooms. The average concentrations of ^{137}Cs and ^{40}K in these common edible mushrooms were calculated from Table 1 and are shown in Table 3. For the calculation of average concentration, values described as 'limit of detection' were also included. Thus, the real average concentrations of ^{137}Cs are expected to be lower than the calculated values shown in Table 3. The average concentrations of ^{137}Cs in *Agaricus bitorquis* and *Lentinula edodes* are <0.05 Bq kg^{-1} and <0.1 Bq kg^{-1} (wet weight) or <1.0 Bq kg^{-1} and <1.3 Bq kg^{-1} (dry weight). The arithmetic mean of the other four species of mushrooms is <0.09 Bq kg^{-1} (wet weight) or <1.1 Bq kg^{-1} (dry weight). Because consumption of the other mushrooms is small, this value is regarded as a representative for the other common edible Taiwanese mushrooms, except *Agaricus bitorquis* and *Lentinula edodes*. Because there are no reports on the consumption quantity of mushrooms in Taiwan, we have calculated the annual consumption of mushrooms in Taiwan to be 0.26, 0.13 and 0.09 kg y^{-1} per capita for *Agaricus bitorquis*, *Lentinula edodes* and the other mushrooms using the difference of production and exports of mushrooms (Council of Agriculture, Taiwan, 1995) divided by the population of Taiwan. The annual intake of ^{137}Cs from ingestion of the common edible Taiwanese mushrooms per capita in Taiwan was calculated to be 0.034 Bq y^{-1} (Table 4), which is only about 0.43% and 0.056% of the annual intake of ^{137}Cs from vegetables (7.83 Bq y^{-1}) and main foodstuffs (60.3 Bq y^{-1}) in Taiwan (Wang *et al.*, 1996). The effective dose equivalent received by individuals from the ingestion of mushrooms containing ^{137}Cs was calculated to be only 4.4×10^{-10} Sv y^{-1} using a dose conversion factor of 1.3×10^{-8} Sv Bq^{-1} (ICRP, 1989). This value is <0.3 and $<2 \times 10^{-5}$% of the annual effective dose equivalent obtained in Japan

Table 3. Average radioactivity concentrations of ^{137}Cs and ^{40}K (Bq kg^{-1}) in the most common edible Taiwanese mushrooms analyzed in this study[a]

	^{137}Cs		^{40}K		
Mushrooms	Wet weight	Dry weight	Wet weight	Dry weight	Dry/wet ratio
A. bitorquis (2)[b]	< 0.05	< 1.0	< 3.7	< 72	0.051
L. edodes (23)	< 0.10	< 1.3	59 ± 9	540 ± 117	0.080
P. cystidiosus (9)	< 0.10	< 1.3	50 ± 38	690 ± 483	0.079
A. polytricha (7)	< 0.09	< 1.2	25 ± 6	320 ± 76	0.079
F. velutipes (6)	< 0.09	< 1.0	100 ± 8	1070 ± 85	0.093
V. volvacea (2)	< 0.09	< 1.0	< 8.4	< 91	0.092

[a] For the calculation of average concentration, values described as 'limit of detection' were also included.
[b] Number of samples in parentheses.

Table 4. Average annual intake of ^{137}Cs from ingestion of the most common edible Taiwanese mushrooms per capita in Taiwan

Mushrooms	Production (kg y^{-1})	Exports (kg y^{-1})	Consumption[a] (kg y^{-1})	Annual intake (Bq y^{-1})	Annual dose equivalent (Sv y^{-1})
Agaricus bitorquis	5,945,000	555,000	0.26	0.013	1.7×10^{-10}
Lentinula edodes	2,687,000	0	0.13	0.013	1.7×10^{-10}
Others	197,000	0	0.09	0.008[b]	1.0×10^{-10}
Total	8,829,000	555,000	0.48	0.034	4.4×10^{-10}

[a] The consumptions were calculated using the difference of production and exports of mushrooms divided by the population of Taiwan (2.1×10^7).
[b] Arithmetic mean of *P. cystidiosus*, *A. polytricha*, *F. velutipes* and *V. volvacea*.

(Muramatsu *et al.*, 1991) and from natural sources, 2.4×10^{-3} Sv y^{-1} (UNSCEAR, 1989), respectively. There are two reasons to explain why the annual effective dose equivalent for Taiwanese (4.4×10^{-10} Sv y^{-1}) due to the dietary intake of radiocesium through mushrooms is smaller than that for the Japanese (1.6×10^{-7} Sv y^{-1}). One is that generally Taiwanese people only eat mushrooms which are cultivated indoors, and the mushrooms cultivated indoors are expected to have lower radiocesium concentrations than wild mushrooms. The other reason is that the consumption of mushrooms for the Taiwanese people (0.48 kg y^{-1} per person, wet weight) is smaller than that for the Japanese people (3.5 kg y^{-1} per person, wet weight) (Muramatsu *et al.*, 1991).

References

Council of Agriculture, Taiwan, R.O.C. (1995) *Agricultural Production Statistics Abstract*. Council of Agriculture, Taipei, Taiwan, Republic of China.

EC/IAEA/WHO (1996) *One Decade After Chernobyl: Summing up the Consequences of the Accident*, International Conference, 8–12 April. International Atomic Energy Agency, Vienna.

Eckl P., Hofmann W. and Turk R. (1986) Uptake of natural and man-made radionuclides by lichens and mushrooms. *Radiation and Environmental Biophysics* **25**, 43–54.

Grueter H. (1971) Radioactive fission product ^{137}Cs in mushrooms in W. Germany during 1963–1970. *Health Physics* **20**, 655–656.

Haselwandter K. (1978) Accumulation of the radioactive nuclide ^{137}Cs in fruitbodies of basidiomycetes. *Health Physics* **34**, 713–715.

Horyna J. and Randa Z. (1988) Uptake of radiocesium and alkali metals by mushrooms. *Journal of Radioanalytical and Nuclear Chemistry* **127**, 107–120.

ICRP (1989) *Age-dependent dose to members of the public from intake of radionuclides (Part* 1), ICRP Publication 56, International Commission on Radiological Protection, p. 57. Pergamon Press, Oxford.

Johnson K. D., Rayie D. L. and Wedberg H. L. (1984) *Biology: An Introduction*, Chap. 13, pp. 216–219. Benjamin/Cummings, California.

Lin Y. M. and Huang C. C. (1988) Dose assessment of the Chernobyl accident in Taiwan. *Nuclear Science Journal* **25**, 294–300.

Mihok S., Schwartz B. and Wiewel A. M. (1989) Bioconcentration of fallout ^{137}Cs by fungi and red-backed voles (*Clethrionomys gapperi*). *Health Physics* **57**, 959–966.

Muramatsu Y., Yoshida S. and Sumiya M. (1991) Concentrations of radiocesium and potassium in basidiomycetes collected in Japan. *The Science of the Total Environment* **105**, 29–39.

Randa Z. (1988) Radiocesium tracer obtained from mushrooms. *Journal of Radioanalytical and Nuclear Chemistry* **126**, 345–349.

The Science and Technology Agency, Japan (1990) *Gamma-ray Spectrometry Using a Gerumanium Semiconductor Detector*, Radioactivity Measurement Series No. 7. Japan Chemical Analysis Center, Japan (in Japanese).

Teherani D. K. (1987) Accumulation of ^{103}Ru, ^{137}Cs and ^{134}Cs in fruitbodies of various mushrooms from Austria after Chernobyl. *Journal of Radioanalytical and Nuclear Chemistry* **117**, 69–74.

Teherani D. K. (1988) Determination of ^{137}Cs and ^{134}Cs radioisotopes in various mushrooms from Austria one year after the Chernobyl incident. *Journal of Radioanalytical and Nuclear Chemistry* **126,** 401–406.

UNSCEAR (1989) *Source, Effects and Risks of Ionizing Radiation*, p. 95. United Nations, New York.

Wang C. J., Lai S. Y., Huang C. C. and Lin Y. M. (1996) Annual intake of ^{137}Cs and ^{90}Sr from ingestion of main foodstuffs in Taiwan. *Journal of Health Physics* **31,** 185–191.