中国疾病预防控制中心
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国家卫生计生委核事故医学应急中心
Chinese Center for Medical Response to Radiation Emergency

Radionuclides in Mushrooms and Soil-to-mushroom Transfer Factors in Partial Areas of China

National Institute for Radiological Protection

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1.Introduction and Objectives

Introduction

- Most radionuclides can be bioaccumulated by mushrooms and ^{137}Cs in wild mushroom species can be detected consistently. It often considered as excellent bioindicators for evaluation of environmental pollution.
- Mushrooms are also consumed by people and directly eaten by animals.
- Regular consumption of these mushrooms or animals may pose a human health concern.
- Therefor, knowing the related information about radioactivity concentration of mushrooms in China is significant to public health.

Journal of Environmental Radioactivity 113 (2012) 150–154

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Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

Artificial and natural radioactivity in edible mushrooms from Sao Paulo, Brazil

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Journal of Environmental Radioactivity 116 (2013) 34–41

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^{210}Po, ^{210}Pb, ^{40}K and ^{137}Cs in edible wild berries and mushrooms and ingestion doses to man from high consumption rates of these wild foods

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Journal of Environmental Radioactivity 116 (2013) 124–132

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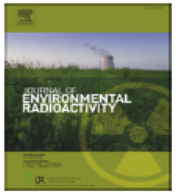

^{137}Cs, $^{239,240}Pu$ and ^{241}Am in boreal forest soil and their transfer into wild mushrooms and berries

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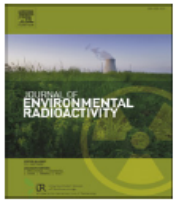

Uptake of ^{137}Cs by berries, mushrooms and needles of Scots pine in peatland forests after wood ash application

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1.Introduction and Objectives

Objectives

- Evaluating ^{238}U, ^{226}Ra, ^{228}Ra, ^{137}Cs and ^{40}K activity concentrations in mushrooms and determining their transfer.

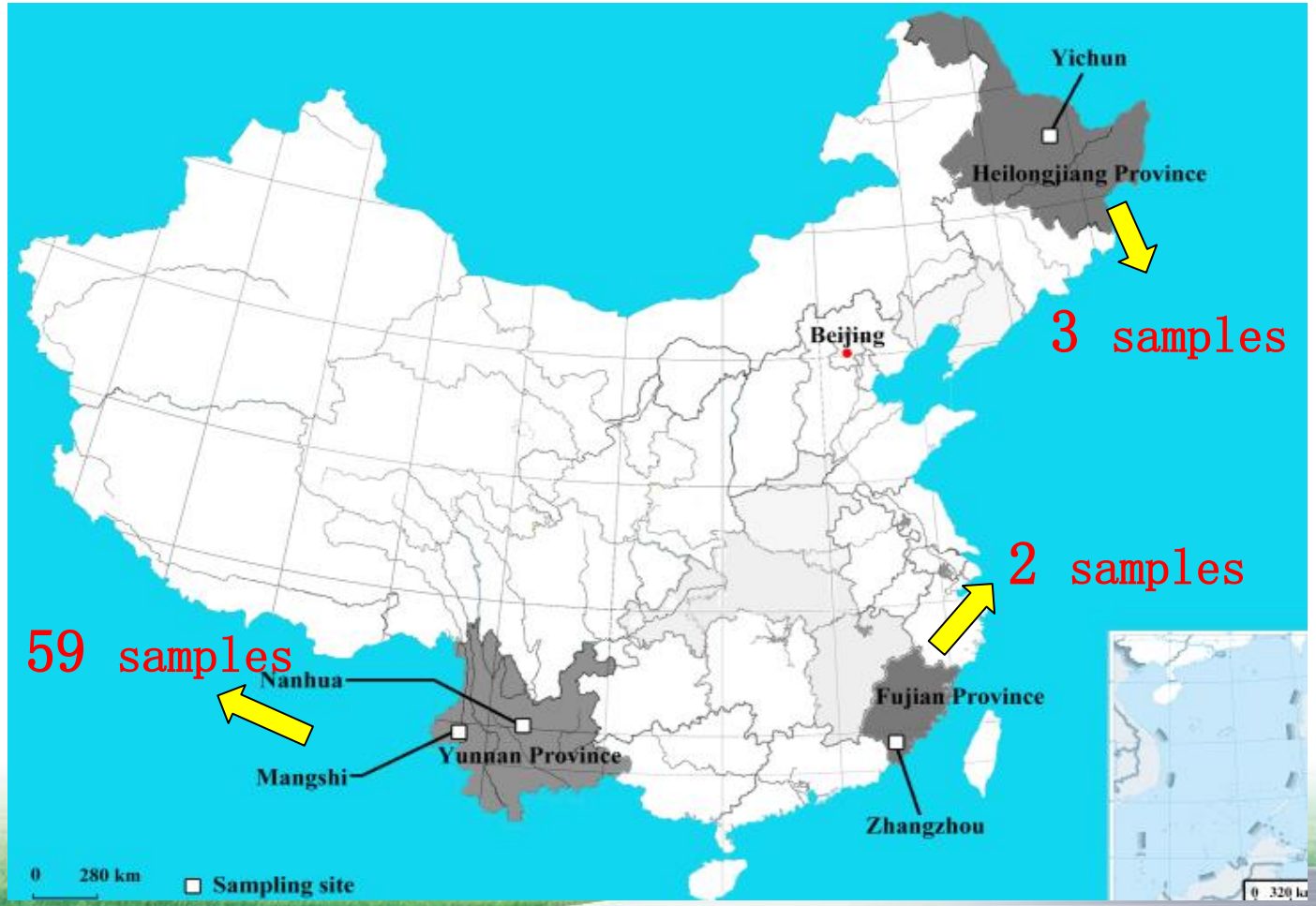
- The present study is the first radioactive content and transfer factor analysis of Chinese originated wild mushrooms.

2.Material and Methods

2.1 Mushroom sampling and sample pre-treatment

A total of 64 wild mushroom samples were collected from following area of China :

Geographical position of sampling site



Picture of some mushrooms

2.Material and Methods

2.1 Mushroom sample pre-treatment

Drying

↓

Grinding into powder

↓

Homogenizing in a domestic blender

↓

Placing in a polyethylene bottle

↓

Sealing the bottle with adhesive tape

↓

Storing the bottle for approximately four weeks

2.Material and Methods

2.2 Soil sampling and sample pre-treatment

Collecting surface soil samples and
Recording latitude and longitude

↓

Identifying soil type and removing stones and pebbles

↓

Drying

↓

Grinding and sieving

↓

Bottling and sealing

↓

Set aside for at least four weeks

2.Material and Methods

2.3 Gamma spectrometry

Instruments and software:

Activities of gamma emitters in mushrooms samples:

GR6019(CANBERRA)

Genie 2000®

LabSOCS®（efficiency calibration tool）

1.71 keV @1332 keV ^{60}Co

53% efficiency

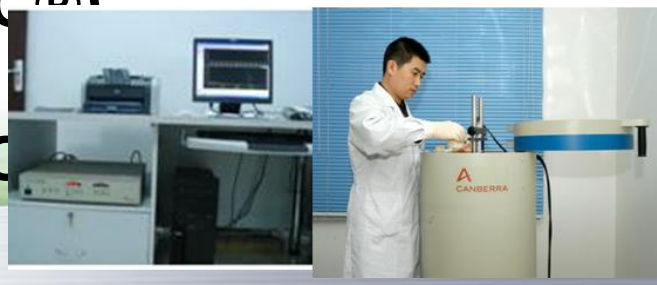
Activities of gamma emitters in soil samples:

GEM50195(ORTEC®)

GammaVision®

1.9 keV @1332 keV ^{60}C

Efficiency of 51%



2.Material and Methods

2.4 Transfer factor determination

$$TF = \frac{A_M(mushroom)}{A_S(surface\ soil)}$$

AM(mushroom)：activity concentration detected in the fruiting bodies,
AS(surface soil)：activity concentration detected in the corresponding surface soil.

Quality control:

- Intercomparison of γ-spectrometry measurement and analysis,JCAC,NIM,NIRP
- Validity of the radiometric methods

$$En = \frac{\left| Value_{laboratory1} - Value_{laboratory2} \right|}{\sqrt{u^2_{laboratory1} + u^2_{laboratory2}}}$$

The result was assigned “acceptable” score if: En≤1,

Validity of the radiometric methods

International Atomic Energy Agency
Analytical Quality Control Services
Wagramer Strasse 5, PO.Box 100, A-1400 Vienna, Austria

REFERENCE SHEET

REFERENCE MATERIAL

IAEA-156

RADIONUCLIDES
IN CLOVER

Date of issue: January 2000⊕

Recommended Values
(Based on dry weight)

Reference Date for decay correction: 1st August 1986

Element	Recommended Value Bq/kg	95% Confidence Interval Bq/kg	N*
^{40}K	657	637 – 676	40
^{90}Sr	14.8	13.4 – 16.3	20
^{134}Cs	132	126 – 138	48
^{137}Cs	264	254 – 274	48

* *Number of accepted laboratory means which were used to calculate the recommended values and confidence intervals.*

⊕ *Revision of the original reference sheet dated January 1991*

The values listed above were established on the basis of statistically valid results submitted by laboratories which had participated in an international intercomparison exercise organized during 1989. The details concerning the criteria for qualification as a recommended value can be found in the report (IAEA/AL/035) "Report on the Intercomparison Run IAEA-156: Radionuclides in Clover" [1]. This report is available free of charge upon request.

International Atomic Energy Agency
Analytical Quality Control Services
Wagramer Strasse 5, PO.Box 100, A-1400 Vienna, Austria

REFERENCE SHEET

REFERENCE MATERIAL

IAEA-321

RADIONUCLIDES
IN MILK POWDER

Date of issue: January 2000⊕

Recommended Values
(Based on dry weight)

Reference Date for decay correction: 1st January 1989

Element	Recommended Value Bq/kg	95% Confidence Interval Bq/kg	N*
^{40}K	552	536 – 569	55
^{90}Sr	3.3	3.16 – 3.44	17
^{134}Cs	15.5	14.8 – 16.2	53
^{137}Cs	72.6	71.1 – 74.2	49

* *Number of accepted laboratory means which were used to calculate the recommended values and confidence intervals.*

⊕ *Revision of the original reference sheet dated February 1990*

The values listed above were established on the basis of statistically valid results submitted by laboratories which had participated in an international intercomparison exercise organized between 1988-89. The details concerning the criteria for qualification as a recommended value can be found in the report (IAEA/AL/026) "Report on the Intercomparison Run IAEA-321: Radionuclides in Milk Powder" [1]. This report is available free of charge upon request.

3.Results and Discussion

3.1 Radionuclides in mushroom samples

The activity concentrations of radionuclides in 64 mushroom samples are given in the following table (Bq/kg^{-1}, dry weight):

Species Latin name	Number of samples	Edible or not*	Originated	^{238}U Median(Range)	^{226}Ra Median(Range)	^{228}Ra Median(Range)	^{137}Cs Median(Range)	^{40}K Median(Range)
Boletus aereus.Fr.:Bull	8	E	Yunnan	2.06(0.2-3.14)	0.24(0.05-0.5)	0.81(0.4-1.34)	1.66(0.83-11.9)	716(626-836)
Boletus brunneissimus W.F.Chin	6	E	Yunnan	3.315(0.18-5.7)	0.75(0.34-1.37)	2.255(0.34-5.11)	0.835(0.58-3.81)	762(708-872)
Boletus edulis bull	6	E	Yunnan	1.19(0.46-3.83)	0.35(0.27-0.65)	1.72(0.65-2.31)	0.7(0.45-2.12)	758(731-830)
Tylopllus bolloul(peck)singer	7	E	Yunnan	2.26(1.35-4.68)	0.55(0.09-1.3)	0.98(0.39-4.15)	2.91(1.06-6.47)	583(539-879)
Lentinu edodes	11	E	Yunnan	1.63(0.49-3.33)	0.29(0.15-0.85)	0.38(0.14-1.32)	8.42(0.13-21.4)	629 (396-1010)
Gomphus floccosus(Schw.) Singer	3	E	Yunnan	3.68(2.83-12.4)	3.65(0.69-7.45)	5.48(3.99-13.9)	212(148-339)	975(896-1877)
Termitomyces alluminosus (Berk.)	3	E	Yunnan	3.44(0.16-4.9)	0.37(0.29-0.53)	0.59(0.47-0.85)	5.87(2.81-13.2)	607(572-711)
Boletus sp.	3	NE	Yunnan	4.01(3.19-6.09)	1.29(1.19-1.43)	5.4(4.38-5.89)	1.24(1.21-1.27)	709(629-780)
Tylopilus felleus (Bull.:Fr.) kuant	3	NE	Yunnan	2.58(0.81-4.39)	0.41(0.16-0.61)	1.94(1.83-3.07)	3.34(3.01-3.91)	760(696-869)

3.Results and Discussion

continue

Species Latin name	Number of samples	Edible or not*	Originated	^{238}U	^{226}Ra	^{228}Ra	^{137}Cs	^{40}K
Cantharellus cibarius Fr.	1	E	Yunnan	7.68	1.39	7.37	0.45	1306
Hygrophorus russula(Fr.)Qael	1	E	Yunnan	2.51	0.25	3.19	3.35	1131
Boletus obscureumbrinus Hongo	1	E	Yunnan	2.33	0.05	1.30	1.82	1084
lycopersicon lycopersicum	1	E	Yunnan	5.16	0.29	1.56	1.71	794
Lactarius volemus(Fr.:Fr.)Fr	1	E	Yunnan	2.91	0.19	1.89	5.80	1020
Lactarius hatsudake	1	E	Yunnan	0.52	0.11	1.60	2.25	644
Agricus blazei murrill	1	E	Yunnan	2.36	0.29	0.41	0.01	1017
Collybia albuminosa	1	E	Yunnan	4.22	0.45	3.50	0.59	966
Agrocybe cylindracea (DC.ex Fr.)R.Maire	1	E	Yunnan	2.56	0.41	0.76	0.01	1262

3.Results and Discussion

continue

Species Latin name	Number of samples	Edible or not*	Originated	^{238}U	^{226}Ra	^{228}Ra	^{137}Cs	^{40}K
Flammulina velutipes (curt. exFr.)Sing.	1	E	Fujian	0.80	0.17	0.77	0.02	839
Pleurotus djamor(Fr.) Boedjin	1	E	Fujian	1.05	2.17	3.39	2.49	1009
Lyophyllum ulmarium(Bull.exFr.)Fuhn	1	E	Heilongjiang	2.75	0.83	1.07	0.43	1010
Tricholoma mongolicum Imai	1	E	Heilongjiang	5.61	1.31	2.01	3.66	1224
Armillaria solidipes	1	E	Heilongjiang	2.05	0.84	2.32	4.59	1457
Median	All species	—	—	2.32	0.39	1.12	2.37	760
Range	All species	—	—	0.16-12.4	0.05-7.45	0.14-13.9	0.01-339	396-1887

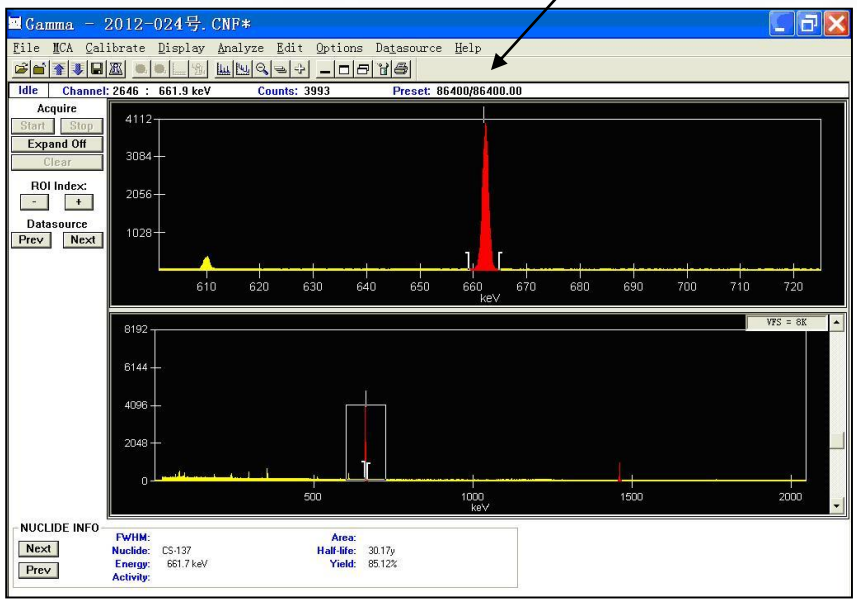
3.Results and Discussion

- The activity concentrations of ^{238}U, ^{226}Ra, ^{228}Ra, ^{137}Cs and ^{40}K in mushrooms varied from 0.16-12.4 Bq/kg^{-1}, 0.05 to 7.45 Bq/kg^{-1}, 0.14 to 13.9 Bq/kg^{-1}, MDC($<$0.01) to 339 Bq/kg^{-1}, 396 to 1877 Bq/kg^{-1}, respectively and the medians activity concentrations of which were 2.32Bq/kg^{-1} , 0.39 Bq/kg^{-1}, 1.12Bq/kg^{-1}, 2.37Bq/kg^{-1}, 760Bq/kg^{-1}, respectively.

- The vast majority of the mushroom samples showed the presence of ^{137}Cs, mushroom named Gomphus floccosus (Schw.) Singer obtained the maximum value(339 Bq/kg^{-1} dry weight or 40 Bq/kg^{-1} fresh weight) for ^{137}Cs, which was lower than the allowed level in China(210 Bq kg^{-1} ,fresh weight) and may be used as a potential good bio-indicator of the ^{137}Cs in the ecosystem.

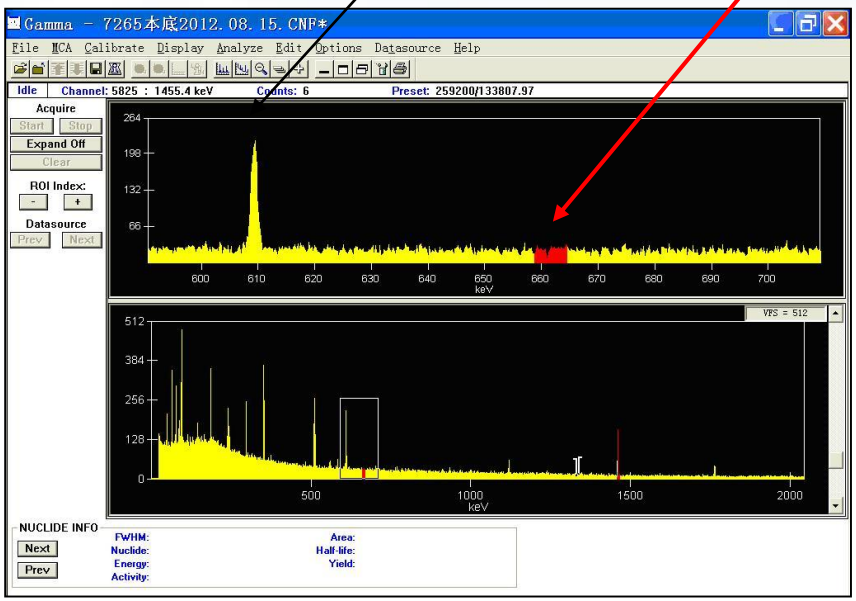
Spectrums of Gomphus floccosus Singer & background

^{137}Cs



Daughter of ^{226}Ra

^{137}Cs



Gomphus floccosus Singer

（Net area=22500，LT=86400s）

Background

（Net area=0，LT=133807s）

3.Results and Discussion

A comparison of reported activity concentrations ranges in mushrooms from the literature are presented in the following table(Bq/kg^{-1}, dry weight):

Country	Number of samples (or species)	^{238}U	^{226}Ra	^{228}Ra	^{137}Cs	^{40}K	Source of information
Norway, Øvre Dividalen	4	—*	—*	—*	167-376	733-986	Justin P. G., Anna N., Geir R., 2013.
Brazil, Sao Paulo	17	—*	14-66	6.2-54.2	1.45-10.6	461-1535	De Castro L.P., Maihara V.A., Silva P.S.C., et al, 2012.
Spain, Munoveros andBazagona	8	0.91-6.8	—*	1.07-6.9	—*	—*	Baeza A.,Guillen J., 2006.
Finland, Parkano and Inari	10	—*	—*	—*	200～19900	—*	Jukka L., Kaisa V., Anumaija L., 2013.
New Zealand, Christchurch and Wellington	—*	0.004	—*	—*	—*	—*	Pearson A.J., Gaw S., Hermanspahn N., Glover C.N., 2016.
Spain	—*	—*	0.021–512	—*	0.4–50,700,000	70–3520	Guillén J., Baeza A., 2014.
Finland, Northern Finland	28	—*	—*	—*	4.4-150	—*	Koivurova M., Leppänen A., Kallio A., 2015.
Netherlands	7	—*	—*	—*	16-136	—*	Brandhoff P.N., Van Bourgondiën M.J., Onstenk C.G.M., et al, 2016.

3.Results and Discussion

- The activity concentration of natural radionuclides(^{238}U、^{226}Ra、^{228}Ra) fell in the range of typical world-wide concentration values.

- Except for G. floccosus, the concentration of ^{137}Cs for most of the species were in agreement with the global fallout levels reported for Brazil, Finland and Netherlands, while lower than those collected in Øvre Dividalen, Norway, Parkano and Inari.

- The reason of which may be the differences between species and the impect of Chernobyl nuclear accident.

3.Results and Discussion

3.2 Radionuclide concentrations in soil samples

Radionuclide concentrations in 15 soil samples are showed in the following table(Bq/kg^{-1},dry weight):

Soil samples	Sample code	$^{238}U^*$	$^{226}Ra^*$	$^{228}Ra^*$	$^{137}Cs^*$	$^{40}K^*$
Soil of Boletus edulis bull	A1	28.3±13.0	29.7±1.0	49.6±2.0	3.2±0.3	432±14
	A2	52.4±11.0	25.2±0.9	57.0±2.2	8.8±0.4	586±19
	A3	27.9±12.4	71.7±2.4	44.8±2.1	2.5±0.4	384±13
Soil of Tylopllus bolloul(peck)singer	B1	34.8±10.7	26.6±0.9	55.7±2.1	8.0±0.4	566±19
	B2	35.4±11.0	33.3±1.1	57.9±2.2	8.0±0.4	575±19
	B3	55.9±10.9	40.9±1.4	54.2±2.1	8.9±0.4	574±19
Soil of Boletus brunneissimus W.F.Chin	C1	38.6±10.9	25.1±0.9	54.0±2.1	8.2±0.4	536±18
	C2	51.5±12.1	29.2±1.0	61.3±2.3	0.8±0.2	610±20
	C3	21.7±10.2	27.5±0.9	49.6±1.9	5.7±0.3	309±10

3.Results and Discussion

continued

Soil samples	Sample code	^{238}U*	^{226}Ra*	^{228}Ra*	^{137}Cs*	^{40}K*
Soil of Boletus sp.	D1	45.7±10.5	33.3±1.1	60.0±2.2	4.0±0.3	705±23
	D2	44.2±8.4	30.3±1.0	63.3±2.3	1.9±0.2	621±20
	D3	42.7±10.1	28.7±1.0	61.0±2.2	2.2±0.2	613±20
Soil of Tylopilus felleus（Bull.:Fr.) karst	E1	34.6±10.1	31.5±1.1	56.8±2.1	11.6±0.5	600±20
	E2	34.3±11.2	27.0±0.9	59.2±2.3	9.2±0.4	577±19
	E3	49.1±10.7	38.7±1.3	59.9±2.2	1.6±0.2	630±21
China ((Zhang et al., 1988))	—	38.51	37.75	56.33	8.05	586.6
Yunnan Province((Zhang et al., 1988))	—	47.8	45.6	67.1	5.98	487
World wild values((UNSCEAR, 2000)	—	33	32	45	—	420
Present work (Median)	—	38.60	29.70	57.00	5.70	577
Present work (Range)	—	22-56	25-72	45-63	1.0-12	309-705

3. Results and Discussion

- **Activity concentrations of radionuclides in top soil samples fell in the range of typical world-wide concentration values.**

- **All samples showed the presence of ^{137}Cs. The studied area did not show any large discrepancy among each sampling point compared with previous investigation data (Zhang, et al.1988) nor did we find any obvious hotspots of ^{137}Cs.**

3. Results and Discussion

3.3 Soil to mushroom Transfer Factors (TF)

The soil to mushroom TF values for different species of mushrooms collected in Nanhua, Yunnan ecosystems were listed in the following ta

Species*	$^{238}U(\times 10^{-2})$	$^{226}Ra(\times 10^{-2})$	$^{228}Ra(\times 10^{-2})$	$^{137}Cs(\times 10^{-1})$	^{40}K
Boletus edulis bull (E)	5.76	1.06	4.65	1.77	1.92
Tylopllus bolloul(peck)singer (E)	8.27	1.66	6.43	4.23	0.95
Boletus brunneissimus W.F.Chin (E)	13.0	4.99	7.65	1.01	1.41
Boletus sp. (NE)	9.07	3.92	9.0	6.69	1.01
Tylopilus felleus (Bull.:Fr.) karst (NE)	7.46	1.07	3.28	3.64	1.21

3. Results and Discussion

- **The TF values for ^{238}U, ^{226}Ra, ^{228}Ra considering all the five species was in the order of 10^{-2}, the medians of the TF values was 8.32×10^{-2}, 3.03×10^{-2}, 6.69×10^{-2}, respectively.**

- **The TF values for ^{137}Cs in individual mushroom of investigated species were in the order of 10^{-1}, the median of which was 0.40 and the range was 0.08–1.94, which were in agreement with previously reported transfer values in Northern Norway.**

- **The literature data available for soil–mushroom TF of ^{238}U, ^{226}Ra, ^{228}Ra is practically inexistent because of it's very large range(10^{-5}-10^{-2}).**

Conclusions

- The results from this work are meaningful for assessing the human radiation exposure.
- It can provide a reference for the study of the geological setting of Southwest China and of international.
- We need cooperation and wish get more technical advise

Thank you!

谢谢!