研究简报

稻米食物链中放射性核素的分布和转移

王　亮　沈秀娟　谷雅琴　侯振海
石本安　王建设　杜白则　沈荣祖
（陕西省预防医学研究所）

摘要　本文研究有关稻米食物链中放射性核素的分布和转移的几个问题：放射性核素从土壤到大米的转移系数；土壤和大米的铀镭平衡系数；大米放射性含量与稻谷品种的关系；稻米与稻糠中的放射性含量比；收晒碾打过程中大米的放射性污染；食用前水淘洗引起大米放射性含量的变化。

文献[1,2]系统地研究了陕西汉中地区稻田土壤和大米的放射性水平，并作了大米所致的内照射剂量估算。在此基础上，本文进一步研究了有关稻米食物链中放射性核素的分布和转移规律。这些问题过去报道甚少。从尽量减少受照剂量这个辐射防护原则出发，搞清这些问题在理论上和实际上都是很有意义的。

一、放射性核素从土壤到大米的转移系数

根据35个采样点的土壤样和相应点上的大米样中天然U、天然Th、^{226}Ra和^{40}K的测值及6个采样点的^{90}Sr、^{137}Cs的测值，应用公式：

$$K = \frac{\text{大米放射性含量}(Bq \cdot kg^{-1})}{\text{土壤放射性含量}(Bq \cdot kg^{-1})}$$

表1　土壤-大米放射性转移系数

元素（核素）	Th	U	^{226}Ra	^{90}Sr	^{137}Cs	^{40}K
转移系数	0.0010±0.0008	0.0014±0.0014	0.0017±0.0018	0.0070±0.0042	0.0079±0.0040	0.176±0.053

求得放射性核素从土壤到大米的转移系数K的均值和标准差，并列于表1。由表1可得其转移系数的比例为：$K_{Th}:K_{U}:K_{^{226}Ra}:K_{^{90}Sr}:K_{^{137}Cs}:K_{^{40}K} = 1.0:1.4:1.7:7.0:7.9:176$。

二、土壤和大米的铀镭平衡系数

由35个采样点的土壤样和相应点的大米样所测之U、^{226}Ra含量，应用U-^{226}Ra平衡系数的计算公式：

表2　常规稻与杂交稻大米放射性水平比较

品　种	样品数	U $\times10^{-6}g \cdot kg^{-1}$	Th $\times10^{-6}g \cdot kg^{-1}$	^{226}Ra $\times10^{-12}g \cdot kg^{-1}$	^{40}K $Bq \cdot kg^{-1}$	总β $Bq \cdot kg^{-1}$
常规稻	16	0.85±0.41	10.9±3.0	5.6±5.5	22.0±4.2	21.9±4.2
杂交稻	18	0.74±0.30	10.0±3.3	5.1±1.9	23.2±4.1	23.7±4.2
偏差(%)		13	8	9	5	8

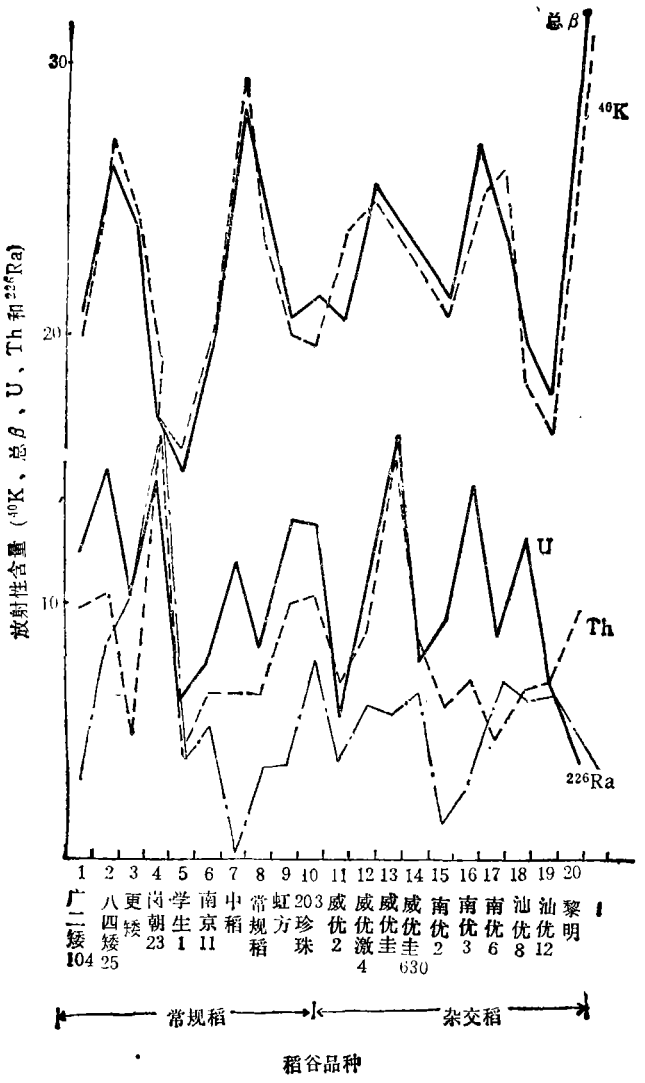

图 1　放射性水平与稻谷品种的关系

单位：U、Th——$\times 10^{-6}$ g · kg^{-1}，^{226}Ra——$\times 10^{-13}$ g · kg^{-1}
^{40}K、总 β——Bq · kg^{-1}

$$k = 2.9 \times 10^6 \cdot \frac{^{226}\mathrm{Ra}}{\mathrm{U}}$$

求得土壤和大米的 U-^{226}Ra 平衡系数 k 的均值和标准差为：$k_{土壤} = 3.2 \pm 1.6$，$k_{大米} = 3.6 \pm 2.6$。$k_{土壤}$ 和 $k_{大米}$ 值都大于 1，表明在土壤和大米中都是富镭的，而且，在大米中可能更富镭。

三、大米放射性含量与稻谷品种的关系

图 1 绘出了大米放射性含量与稻谷品种的关系曲线。从中看出，^{40}K 与总 β 的变化规律一致，U、Th、^{226}Ra 变化规律基本一致。表 2 列出常规稻与杂交稻大米中放射性含量的均值及相对偏差，从中看出，总 β 与 ^{40}K 的放射性含量有杂交稻高于常规稻的趋势；U、Th 和 ^{226}Ra 则有与此相反的趋势。但在 $\alpha = 0.01$ 时，均无显著性差异。

四、稻米与稻糠中的放射性含量比

在六块稻田里，在植株上直接采集稻谷样品，使其在收晒碾打过程中不受污染，然后对米灰与糠灰进行分析，由测得之放射性含量计算米与糠的放射性含量比，其结果列于表 3。

由表 3 看出，在稻谷中，米重显著地大于糠重，但其放射性含量，则

表 3　稻米与稻糠中的放射性含量比(%)

样品号	米/糠	U	Th	^{226}Ra	^{40}K	^{90}Sr	^{137}Cs	总 β
1	0.687/0.313	6.2	10.5	2.2	35.3	65.3	8.3	25.6
2	0.635/0.365	6.9	7.7	7.9	32.6	39.2	9.0	22.7
3	0.670/0.330	5.9	5.8	6.1	29.2	29.6	12.6	23.0
4	0.682/0.318	8.0	13.1	10.4	22.8	35.9	15.1	23.1
5	0.658/0.342	7.1	15.6	12.9	23.7	4.7	5.4	22.4
6	0.688/0.312	9.3	32.8	8.4	33.2	11.8	41.0	28.0
均　值	0.670/0.330	7.2±1.2	14.2±9.8	8.0±3.7	29.5±5.2	31±22	15±13	24.1±2.2

糠明显地高于米，当平均米糠比为 0.670：0.330 时，稻谷中被测之放射性含量的米糠比，可能存在如下顺序：U < ^{226}Ra < Th < ^{137}Cs < 总 β < ^{40}K < ^{90}Sr。从辐射防护上讲，谷糠堪称是一个天然的屏障。

五、收晒碾打过程中大米的放射性污染

在六个采样点上，采集两类大米样品：I. 农民实际收晒碾打而得之大米；II. 我们特意在稻田的植株上直接采集并保证收晒碾打过程中不受环境污染的大米。对这两类大米样进行分析，其结果列于表 4。

从表 4 看出，稻谷在收晒碾打过程中使大米受到了 U、Th、^{226}Ra 环境放射性污染，其污染程度依次高达约139%、197%、228%；而基本上未受到 ^{40}K、^{90}Sr、^{137}Cs 和总 β 的污染。其污染可能主要产生于晾晒碾打过程，如有的地方在沥青路面上晾晒碾打。

六、食前用水淘洗引起大米放射性含量的变化

取六个大米样品，每个样品分为两份：水洗和不水洗。水洗方法采用居民饭前实际的习惯洗米方法，用足量的自来水淘洗大米 3—5 次，然后将水洗与不水洗的米样，在同样条件下炭化、灰化和分析。实验结果列于表 5.

从表 5 看出，水洗与不水洗比较：(1) Th、^{226}Ra、^{40}K、^{137}Cs。总 β 放射性含量分别依次降低了 81%、83%、48%、24%、45%；(2) ^{90}Sr 含量基本无变化；(3)U 水洗后反而升高了 407%，其升高的原因可能主要是由于水洗造成的损失远远小于大米对自来水中 U 的富集。我们用含 U 量分别为 0.315 × 10^{-6} g/L 和 2.76 × 10^{-6} g/L 的去离子水和自来水淘洗同一大米样品，测得大米 U 含量分别为 0.186 × 10^{-6} g · kg^{-1} 和 4.70 × 10^{-6} g · kg^{-1}，二值之比高达 25.3 倍。以此可以

表 4　收晒碾打过程中大米的放射性污染

样品号	U		Th		^{226}Ra		^{40}K	
	I	II	I	II	I	II	I	II
1	0.406±0.011	0.265±0.007	6.00±0.00	2.09±0.21	4.91±0.37	0.62±0.87	15.73±0.50	26.53±0.80
2	0.76±0.13	0.410±0.030	8.57±0.57	2.92±0.54	6.98±0.19	3.05±0.37	21.4±1.0	29.18±0.39
3	1.12±0.23	0.220±0.000	8.98±0.59	1.50±0.18	21.32±0.40	0.86±0.08	26.74±0.84	24.6±1.1
4	0.564±0.029	0.255±0.001	8.23±0.47	2.26±0.54	12.1±1.3	3.66±0.57	23.58±0.47	19.0±1.1
5	0.69±0.07	0.255±0.007	14.21±0.28	4.62±0.44	3.78±0.23	4.21±0.00	25.25±0.50	22.01±0.57
6	0.608±0.027	0.330±0.014	11.08±0.47	5.55±0.33	<MDL	2.4±1.8	29.6±1.4	27.33±0.23
$\bar{X}\pm S$	0.69±0.24	0.289±0.069	9.5±2.8	3.2±1.6	8.2±7.6	2.5±1.5	23.7±4.8	24.8±3.7
污染率	139%		197%		228%		−4.4%	

样品号	^{90}Sr		^{137}Cs		总 β	
	I	II	I	II	I	II
1	0.0100±0.0071	0.202±0.045	0.013±0.000	0.019±0.001	14.7±0.2	20.3±0.2
2	0.040±0.020	0.124±0.035	0.029±0.006	0.026±0.003	28.8±0.3	24.6±0.2
3	0.082±0.020	0.087±0.029	0.100±0.003	0.025±0.004	23.1±0.2	21.3±0.2
4	0.049±0.022	0.113±0.034	0.029±0.003	0.019±0.001	28.3±0.3	20.9±0.2
5	0.047±0.022	0.031±0.18	0.019±0.003	0.019±0.001	23.7±0.3	22.1±0.2
6	0.031±0.018	0.056±0.024	0.046±0.005	0.102±0.001	27.5±0.3	23.2±0.2
$\bar{X}\pm S$	0.043±0.024	0.102±0.06	0.039±0.032	0.035±0.033	24.4±5.3	22.1±1.6
污染率	−57%		11%		10%	

注：U、Th 单位为 $\times10^{-6}$ g · kg^{-1}，^{226}Ra 为 $\times10^{-13}$g · kg^{-1}，^{40}K 总 β 为 Bq · kg^{-1}

表 5　水洗引起大米放射性含量的变化

样品号	U		Th		^{226}Ra		^{40}K	
	水洗	不洗	水洗	不洗	水洗	不洗	水洗	不洗
1	4.70±0.13	0.406±0.011	0.78±0.00	6.00±0.00	1.43±0.15	4.91±0.37	8.70±0.07	15.73±0.50
2	1.41±0.07	1.12±0.23	2.10±0.32	8.98±0.59	3.00±0.34	6.98±0.19	15.05±0.13	26.74±0.84
3	2.48±0.12	0.564±0.029	2.14±0.04	8.23±0.47	3.08±0.07	21.32±0.40	12.05±0.10	23.58±0.47
4	7.33±0.00	0.688±0.070	1.36±0.11	14.21±0.28	0.35±0.49	12.1±1.3	13.44±0.11	25.25±0.50
5	2.58±0.11	0.608±0.027	2.42±0.11	11.08±0.47	<MDL	3.78±0.23	13.81±0.12	29.58±1.4
6	2.50±0.11	0.76±0.13	2.25±0.34	8.57±0.57	0.50±0.70	<MDL	11.36±0.10	21.4±1.0
$\bar{X}\pm S$	3.5±2.2	0.69±0.24	1.84±0.63	9.5±2.8	1.4±1.4	8.2±7.6	12.4±2.2	23.7±4.8
去污率(%)	−407%		81%		83%		48%	

样品号	^{90}Sr		^{137}Cs		总β	
	水洗	不洗	水洗	不洗	水洗	不洗
1	0.0429±0.0207	0.0100±0.0071	0.0347±0.0000	0.0134±0.0000	8.99±0.11	14.7±0.2
2	0.0455±0.0213	0.0820±0.0201	0.0411±0.0043	0.1002±0.0028	12.40±0.10	23.1±0.2
3	0.0540±0.0232	0.0492±0.0222	0.0189±0.0027	0.0288±0.0026	16.31±0.20	28.3±0.3
4	0.0551±0.0235	0.0466±0.0216	0.0316±0.0011	0.0188±0.0029	13.75±0.20	23.7±0.3
5	0.0296±0.0172	0.0311±0.0176	0.0293±0.0000	0.0463±0.0048	14.60±0.20	27.5±0.3
6	0.0385±0.0196	0.0396±0.0199	0.0242±0.0000	0.0292±0.0055	14.40±0.20	28.8±0.3
$\bar{X}\pm S$	0.0443±0.0096	0.0431±0.0237	0.0300±0.0078	0.0394±0.0318	13.4±2.5	24.4±5.3
去污率(%)	−2.8%		24%		45%	

注：所用单位与表 4 相同，参加本工作的还有：李辑银、李建萍、张淑身、李天来.

证明大米对水中 U 具有强的富集能力。

参 考 文 献

[1] 王　尧等，辐射防护，4，312(1987)。

[2] 王　尧等，环境科学，8(5)，60(1987)

(收稿日期：1988 年 6 月 1 日)

京津大气颗粒物区域性的污染特征

陈宗良　张远航　马慈光　何芬珠

(中国科学院生态环境研究中心)

摘要　本文研究了京津地区大气颗粒物及其化学组成，介绍 12 种元素 Cd、Cu、K、Mn、Pb、Zn、Fe、Na、Ni、Cr、Sr、Ba；5 种离子 F^-、Cl^-、NO_3^-、SO_4^{2-}、NH_4^+ 和 26 种有机污染物的区域分布. 用有机物的奇/偶碳数比值估计了大气颗粒物的来源. 用无机元素的判别法分析了北京、天津、廊坊和蓟县之间大气污染的相互影响.

京津地区大气污染基本上属煤烟型，颗粒物的污染显得突出和严重. 但是以往本地区的研究多是将采样器放在离地面 1.5 米左右的呼吸带处，其结果是受地面风砂的直接

Abstracts

HUANJING KEXUE Vol. 10 No. 4, 1989
Chinese Journal of Environmental Science

Controlling the Spread of Environmental Pollution and Ecological Deterioration ——Comment on the Third Conference of Environmental Protection

Guo Fang (Vice-director, The Committee of Environmental Science, Academia Sinica, Beijing)

Based on the current environmental situation in China and the environmental goals till 1992 and 2000, which have been pronounced in the Third National Conference of Environmental Protection, the author encourages environmental scientific and technological workers especially those in the Chinese Academy of Sciences should strive to fulfill the tasks. (See pp. 10—13)

Effective Factors of Deep Oxidation of Methanol on Pt/Al_2O_3 Catalyst

Jin Yun, Yu Qiquan and Cao Peilie (Department of Chemistry, Peking University, Beijing)

The effect of intraparticle diffusion of catalyst has been investigated in a flow-recirculation gradientless reactor. The kinetics of deep oxidation of methanol with 30-40 mesh catalyst on Pt/Al_2O_3 in the kinetic regime obeyed the Langmur-Hinshelwood model of adsorption of methanol and oxygen with inhibition of carbon dioxide. When the temperature of reaction increased to 80°C and the particle size of catalyst increased to 6×2 mm, the deep oxidation of methanol occurred on the regime of intraparticle diffusion. The effect of intraparticle diffusion increased as reaction temperature increased. The values of catalytic effective factors were measured as 0.44—0.22. The effect of intraparticle diffusion has been interpreted with the approximation method of general reaction rate forms (See pp. 6—9)

Effect of Mercury on the Growth and Physiological Function of Wheat Seedlings

Zhang Zhijie, Lu Qiufen and Fang Fang (Xi'an Institute of Metallurgy and Construction Engineering, Xi'an, Shaangxi Province)

It has been observed that mercury depressed the germinant rate of wheat and its seedling growth, decreased its transpiration and chlorophyll content. Degrees of the influence was directly related with the mercury concentrations in wastewater and the content of it in the seedlings. In low concentration of mercury, the respiratory rate of seedlings increased, but it decreased or increased considerably in accordance with its high concentrations. Moreover, the respiratory rate in the growth and stages of the seedlings. The result showed that mercury caused a change of peroxidase isozyme pattern. The effects of mercury on wheat seedlings were a physiological reaction due to injury of mercury. (See pp. 10—13)

An Automatic and Continuous Analyzer of COD

Zhu Wansen et al. (Department of Chemistry, Fudan University, Shanghai)

An automatic COD analyzer has been designed. A pump is used as a driving force to control operation of the eletromagnatic valves in the pipeline, by which volume control of wastewater samples and reagents, digestion, photometric measurement and cleaning in the process are carried out orderly. These procedures can be automatically repeated for continuous monitoring. This instrument is convenient for rapid determination of COD, 5—8 samples per hour can be analyzed. The results match with the ones abtained by the standard methods, relative standard deviation is 1.9% for 10 samples determined. (See pp. 13—16)

Reclamation of L-Proline and Other Amino-Acids from Chrome Leather Scraps

Jiang Tingda and Zhang Chunping (Research Center for Eco-Environmental Sciences, Academia Sinica, Beijing)

The scraps of chrome leather is a tanning waste. The process of reclaiming six amino-acids was operated as follows: de-chroming of the scraps was adopted by basic hydrolysis with calcium oxide, and the protein extracted; the protein was hydrolyzed with 6 mol HCl; the hydrolysate was declorized with activated carbon; then separated by 732 cation exchange resin (H form) and 717 anion exchange resin (OH form) respectively. L-Arg, L-Pro, L-Asp, L-Ala and Gly were obtained. (See pp. 17—20)

Distribution and Migration of Redioactive Nuclides in Paddy Food Chains

Wang Liang et al. (Shaanxi Provincial Research Institute of Preventive Medicine, Xi'an)

On the basis of what radioactive levels existing in soil and rice around Hanzhong region of Shaanxi Province were studied as the references (1) and (2), the following problems have been discussed in this paper: the transmitted coefficient of radioactive nuclides from soil to rice, U-Ra equilibrium coefficient in soil and rice, the relationship between nuclide content in rice and the paddy species, the ratio of nuclide contents in rice and in rice bran, rice polluted by radioactive nuclides in the course of harvesting and husking, and viriations of nuclide content in rice after washing. (See pp. 21—24)

Regional Contaminant Features of Suspended Particulates in Beijing-Tianjin Area