

## 监测分析

# 用裂变径迹法测量兰州自来水中铀的含量

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**摘要** 在反应堆中,用慢中子辐照经过处理的自来水样品,使铀裂变碎片在聚碳酸酯中产生径迹,经化学蚀刻放大后用光学显微镜观测径迹数。

在自然界中天然铀分布很广,它存在于岩石、土壤、矿物、水、生物和空气中,以多价态(+3,+4和+6价)的形式出现,其化学性质十分活泼,绝大多数的化合物溶于水。由于地区的不同,矿岩、土壤、水中的铀含量可能有较大的差别,即使是同一地区也会有差异。随着矿藏的开发利用,大量铀被释入空气和水中,致使水中的铀含量增大,又经饮水进入人体。同时,土壤通过灌溉所富集的铀,会经生物链转移到人体。由于天然铀对人体既有放射性损伤又有化学性毒害<sup>[1]</sup>,所以监测水中的铀含量是十分必要的。有关资料<sup>[2-5]</sup>报道了湖水、河水、自来水和地下水中的铀含量。我们曾用裂变径迹法测量了黄河兰州段水中的铀含量和人尿中的铀含量<sup>[6-7]</sup>。本文报告兰州自来水中铀含量的实测结果。

## 一、实验原理

把水样滴在固体径迹探测器上,放入热中子场中辐照,水中的铀就会产生裂变,产生的裂变碎片射入固体径迹探测器中,在经历的路径上致使物质损伤,形成潜伏径迹。潜伏径迹经化学蚀刻被扩大,可用光学显微镜观测水样区的径迹数。

用下面两种方法计算了水中的铀含量。

### (1) 绝对测量法

$$C_{u1} = \frac{A_u N_t}{N_A \rho V C_{235} \hat{\sigma} \phi \varepsilon} \quad (\text{g/L}) \quad (1)$$

式中, $A_u$ 为天然铀的原子量; $N_A$ 为阿伏加德罗常数; $C_{235}$ 为 $^{235}\text{U}$ 同位素在天然铀中的相对丰度; $\hat{\sigma}$ 为 $^{235}\text{U}$ 的热中子有效裂变截面; $\rho$ 为水的密度; $\phi$ 为等效于2200m/s的中子积分通量; $V$ 为水的取样体积; $\varepsilon$ 为聚碳酸酯的探测效率; $N_t$ 为水样区裂变径迹数(扣除本底的径迹数); $C_{u1}$ 为水样中单位体积的铀含量(g/L)。

### (2) 相对测量法

$$C_{u2} = \frac{N_t V_{\text{标}} C_{u\text{标}}}{N_{\text{标}} V_{\text{水}}} \quad (\text{g/L}) \quad (2)$$

式中, $C_{u\text{标}}$ 和 $C_{u2}$ 分别是标样和水样中的铀含量; $V_{\text{标}}$ 和 $V_{\text{水}}$ 分别是标样和水样的取样体积; $N_{\text{标}}$ 和 $N_t$ 分别是标样和水样的裂变径迹数。

## 二、实验方法

(1) 样品采集 兰州自来水厂共有四个分厂,一分厂和二分厂设在西固城,三分厂设在七里河区,四分厂设在安宁区。1984年6月14日—16日取各分厂内和供水线上的水样,又取了五泉山的矿泉水样。

(2) 样品制备 在经清洁处理的聚碳酸酯薄膜上,用微量进样器滴上一定体积的水样和标准样品,每个样品制成同样的四个平行样。然后夹在两片经清洁处理的聚碳酸酯之间,用铝箔包好送进反应堆照射。同一水样前后一共进行了两次试验,所辐照的热中子积分注量分别为 $4.12 \times 10^{16}$ 个/cm<sup>2</sup>和 $3.3 \times$

$10^{15}$  个/cm<sup>2</sup>。

(3) 测量 照射后的水样经过冷却, 取出聚碳酸酯, 用水洗掉水样痕迹, 在 6.25mol/L 的 NaOH 水溶液和 50℃ 的条件下, 蚀刻 80 分钟, 然后用水冲掉溶液, 晾干后在光学显微镜下观测水样区的裂变径迹数, 并在远离水样区测同样面积的本底径迹数。

### 三、实验结果与分析

所测的裂变径迹数先按平行样数求平均, 然后按每个分厂所取的厂内和供水线的水样求平均( $N_i$ )。按公式(1)和(2)分别计算了兰州自来水中的铀含量, 其结果列于表 1 中。由表可看出两种方法均相差 5.6%, 存在着一个系统误差。本文主要以绝对测量法为主, 按公式(1)给出的实验误差在 10% 以内,

表 1 两种实验方法测量结果

	一分厂	二分厂	三分厂	四分厂	五泉山	标样
$N_i$ (条)	16586	15574	15591	10364	17228	1541
$(\times 10^{-5} \text{g/L})$	7.11	6.67	6.68	4.44	7.38	6.60
$(\times 10^{-5} \text{g/L})$	6.72	6.31	6.22	4.20	6.98	6.24*
两方法相差 (%)	5.64	5.66	5.63	5.63	5.64	5.62

\* 此值是用化学法分析结果

可见两种方法在实验测量误差范围内基本一致。按公式(1)计算出的结果列在表 2 中, 由表 2 可以看出兰州自来水中的铀含量在  $(4.4-7.4) \times 10^{-6} \text{g/L}$  之间。一、二分厂的水直接来自黄河, 它们的抽水站在西固公路大桥以上到东川以下, 1983 年丰水期经陈怀录等<sup>[6]</sup>用裂变径迹法测得此区间黄河水中的铀含量为  $(2.95-14.3) \times 10^{-6} \text{g/L}$ , 1984 年

表 2 兰州自来水中的铀含量 ( $\times 10^{-6} \text{g/L}$ )

	一分厂	二分厂	三分厂	四分厂	五泉山
铀含量	$7.1 \pm 0.7$	$6.7 \pm 0.6$	$6.7 \pm 0.6$	$4.4 \pm 0.4$	$7.4 \pm 0.7$

丰水期本实验测得两个分厂的水中铀含量在

此范围内。

三分厂和四分厂的水源来自黄河滩和黄河边的地下水, 其铀含量既受黄河水中铀含量的影响, 又受地下水和土壤及沙泥中铀含量的影响, 所以这两个厂水中的铀含量要比丰水期此段黄河水的铀含量  $(2.95-2.79) \times 10^{-6} \text{g/L}$ <sup>[6]</sup> 高。五泉山矿泉水中的铀含量为  $7.4 \times 10^{-6} \text{g/L}$ , 比自来水要高, 这是因为矿岩和土壤中的铀含量比较高, 当地下水流经它们时, 其中的铀被水洗刷溶于水中, 故使地下水中的铀含量增高。表 3 列出了几个地区自来水的铀含量。从表 3 可看出, 兰州自来水的铀含量和北京的相差不大, 下限比北京的高两倍, 上限基本一致。如果取平均值, 每人每天饮 2.2L 水时, 兰州人将每天有 13.0  $\mu\text{g}$  的铀进入人体, 比北京人的 11.0  $\mu\text{g}$  略高, 而在广西某地的 1.76  $\mu\text{g}$ <sup>[8]</sup> 高出近十倍。

表 3 不同地区自来水中的铀含量比较

地 区	铀含量 ( $\times 10^{-6}$ 克/升)	分析方法
美国 <sup>[4]</sup>	0.11—6.4	
北京 <sup>[2]</sup>	2.85—7.11	裂变径迹
兰 州	4.4—7.4	裂变径迹 (本工作)

按绝对法计算的实验误差, 主要是中子积分注量的误差 (为 6%), 探测器探测效率的误差为 4.2%, 取样体积的误差为 5%, 有效裂变截面的误差为 2%, 还有计数的统计误差等, 总误差  $< 10\%$ 。

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Copper adsorption characteristics and its influence on the vegetable growth in purple soil collected from Sichuan Province were studied. The results showed that copper adsorption was dependent on the types of soil, and characteristic index of Cu sequentially decreased from No. S<sub>03</sub> soil to S<sub>01</sub> soil and has a great influence upon the vegetables. For a given crop, the same critical intensity index of copper toxicity could be obtained in different soil, e.g. 0.5 µg Cu/ml of soil solution for lettuce and 2.5 µg Cu/ml for cayenne pepper. It was concluded that adsorption method could be used to assess Cu toxicity threshold.

### The Effects of Tourism and Urbanization on Soil and Plants at the Summer Villa, Chende City.

Jiang Gaoming, Huang Yinxiao (Institute of Botany, Academia Sinica, Beijing): *Chin. J. Environ. Sci.*, 11(1), 1990, pp.

In order to study the impact of both tourism and urbanization, the authors have investigated soil and plants at the Summer Villa, a former imperial garden in Chende City of Hebei Province. The results show that soil density and alkalinity have increased, and soil aeration decreased. Sulphur concentration in soil is 2.1 times higher as in Beijing Botanical Garden, and plants have been injured by pests and pollution, for example, lots of old pine trees died in past few years. In addition, the authors proposed some ecological strategies to handle the problems.

### Correlation between Fluoride Pollution in Air and Fluoride Contents in the Tree Leaves.

Dun Wanru et al. (Qingdao Municipal Institute of Environmental Protection, Shandong Province): *Chin. J. Environ. Sci.*, 11(1), 1990, pp.

The aim of this work is to monitor quantitatively fluoride pollution in air by detecting its content in the tree leaves. The result shows that the correlation between them is remarkable. Moreover, as fluoride content accumulating in the tree leaves in various periods has been determined, fluoride pollution in the air of the area can be assessed by application of the regression equation built.

### Investigation of Contents of Total Mercury in Fishes in the Huluen Lake, Inner Mongolia.

Ha Luen, Bai Shaoli and Xiao Tianmin (Research Institute of Environmental Protection of Inner Mongolia Autonomous Region, Huhehaote): *Chin. J. Environ. Sci.*, 11(1), 1990, pp.

The primary aim of this work is to investigate mercury pollution in fishes in the Huluen Lake, the largest fresh water lake in Inner Mongolia. Ninety fishes in nine spe-

cies have been sampled from the lake. Data of total mercury in each fish with determination of cold atomic absorption method are in range of 4.69—171.00 µg/kg, and average value 42.12 µg/kg. Among the fishes, the highest content of mercury is in *Barasilurus asotus* (88.72 µg/kg), the second is in *Cyprinus carpio haemulonius* (Tem) (75.35 µg/kg), and the next are *Erythrulter mongolicus* and *Corassius*. However, in rest five species of fishes, mercury contents are lower. In addition, the mercury accumulated contents in the fishes are consistent with their ages, lengths and weights.

### Mechanism of Biological Removal of Phosphorus from Sewage.

Zheng Xingcan (Design Institute of Municipal Engineering of North China, Beijing): *Chin. J. Environ. Sci.* 11(1), 1990, pp.

The paper briefly summarizes the work on mechanism for enhancing biological removal of phosphorus. Release of phosphate from sludge primarily depends on the nature of substrate interacting with the poly-p bacteria, not on creation of an anaerobic state per se. In the anaerobic state, the readily biodegradable soluble COD can be converted to terminal products (acetate and NADH+H<sup>+</sup>) of EM pathway by acidogenic microflora. The accumulated NADH+H<sup>+</sup> will stop the EM reaction and/or kill bacteria. Poly-p bacteria will utilize poly-p for energy to absorb these terminal products and convert them into poly-β-hydroxybutyrate (PHB) in cell. The phosphate release takes place at the same time. In the presence of oxygen (or NO<sub>3</sub>-N) PHB will be degraded to produce energy. The energy can be used for phosphate uptake and poly-p synthesis. The magnitude of phosphate uptake is proportional to that of anaerobic phosphate release (2.4 mg P uptake/mg P released).

### Determination of Uranium Contents in Tap Water of Lanzhou City and in Mineral Water of the Wuquan Mountain Using Fission Track Method.

Yang Huazhong, Chen Huailu (Dept. of Modern Physics, Dept. of Geography, Lanzhou University, Lanzhou): *Chin. J. Environ. Sci.* 11(1), 1990, pp.

This paper describes how the fission track method was used for determining uranium in tap water and mineral water sampled from Lanzhou and the Wuquan Mountain respectively. The natural uranium concentration were calculated in absolute and relative measurements. The quantitative difference of both results obtained was 3.6%. The concentration range of uranium calculated with the absolute measurement was  $4.4-7.4 \times 10^{-6}$  g/L, and the total experimental error was within 10%. The uranium concentration in mineral water is higher. Compared with uranium concentration in tap water of Beijing, (continued on inside back cover)

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the lowest value in Lanzhou was high twice as much, but its highest value was similar to that in Beijing.

### **Application of Chemiluminescence Analysis to Environmental Detection.**

Li Xiaohu, Lu Minggang (Department of Applied Chemistry, University of Science and Technology of China, Hefei): *Chin. J. Environ. Sci.*, 11(1), 1990, pp.

The application of chemiluminescence analysis to environmental detection has been reviewed in this paper, in which the chemiluminescence detection of metal ions, inorganic compounds, organic compounds and biomass, and the chemiluminescence detection of air pollution are explained.

### **Characteristics of Acid Rain in China and Primary considerations of the Strategies.**

Xu Kangfu, Hao Jiming (Research Institute of Environmental Engineering, Tsinghua University, Beijing): *Chin. J. Environ. Sci.*, 11(1), 1990, pp.

This article introduces briefly the control strategies for acid precipitation abroad and the main features of acid rain in China. Based on variant effects of the components of airborne particulates and acidity of precipitation, the attention should be paid to sources of SO<sub>2</sub> emission, ascertainment of the main controlling factors and selection of environmental goal. According to the present situation of investigation, the authors have offered a suggestion on methodology and principles of the strategies for controlling acid deposition in China.

### **Optimum Distribution of Industrial Water in Shenyang City and Analysis of Its Economic Benefit.**

Bian Maoxin et al. (Liaoning Provincial Institute of Environmental Protection Sciences, Shenyang); Xu Hongtao (National Environmental Protection Agency, Beijing): *Chin. J. Environ. Sci.*, 11(1), 1990, pp.

This paper describes the principles of linear programming applied in Shenyang City for optimum distribution of industrial water. From the viewpoint of water resources, the direction for adjusting industrial structure of the city is proposed. The authors have studied the calculating method of economic benefit for optimizing industrial water distribution. The results show environmental economic benefit is obvious according to calculation.

### **System Design of A Regional Environmental Management Information System—Software and Hardware Environment and Main Menu.**

Situ Wei, Chen Shentong et al., (Department of Environmental Engineering, Tsinghua University, Beijing): *Chin. J. Environ. Sci.*, 11(1), 1990, pp.

This article outlines the principles and procedures of the system design of a Regional Environmental Management Information System (REMIS), in which modular design method has been used. The REMIS hardwares selection, software environment hierarchical relations of the functional modules and main menu of the REMIS have been discussed in detail. Hardware selection should reach identity of system functions, cost/benefit analysis and expansibility.

### **Current Environmental Situation of the Liaodong Peninsula (Dalian Area) and Its Integrated Renovation.**

Chen Tao et al. (Institute of Applied Ecology, Academia Sinica, Shenyang): *Chin. J. Environ. Sci.*, 11(1), 1990, pp.

The ecological environment of Dalian area in the Liaodong Peninsula, as a whole, is getting deteriorated. Three main countermeasures should be taken to harness these environmental problems: (1) rational utilization of natural resources for controlling water pollution and soil erosion; (2) readjustment of distribution of industrial trades and removal of major industrial construction northward; (3) Development of agricultural economy, speeding up agro-ecological construction so as to avoid soil erosion.

### **Research on Natural Radionuclide Levels in Soil in Fujian Province, Southeast China.**

Gao Weiwei et al. (Provincial Institute of Environmental Protection Science, Fuzhou): *Chin. J. Environ. Sci.*, 11(1), 1990, pp.

This paper reports the natural radionuclide levels in soil in Fujian Province. 248 soil samples were collected and tested by using spectrometric and radiochemical analysis method. The results showed that average concentration for U-238 was 55.5 Bq/kg (13.9—136 Bq/kg), Th-232 97.1 Bq/kg (19.5—260 Bq/kg), Ra-226 62 Bq/kg (18—201 Bq/kg) and K-40 627 Bq/kg 24—1627 Bq/kg), and that natural radionuclide contents were different with topographical features, land forms and soil types, which were higher than those in the normal areas home and abroad.

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