Available online at www.sciencedirect.com
ScienceDirect

Nuclear Science and Techniques, Vol.18, No.2 (2007) 115–117

NUCLEAR SCIENCE AND TECHNIQUES

Measurements of ^{134}Cs and ^{137}Cs in urine and estimation of the internal dose of an adult exposed to the Chernobyl Accident

ZHAO Shuquan[1] HUANG Shibin[2] LIU Shiming[3] HU Heping[1]
WU Mingyu[1] XIANG Xiqiao ZHU Guoying[1*]

([1] Institute of Radiation Medicine, Fudan University, Shanghai 200032, China;

[2] Shanghai Medical College, Fudan University, Shanghai 200032, China;

[3] Jinan Maritime Safety Administration of China, Jinan 250062, China)

Abstract To estimate the internal dose of a Chinese visiting scholar internally contaminated because of the Chernobyl Accident, the contents of ^{134}Cs and ^{137}Cs in urine were measured using a Ge(Li) γ-spectrometer. The internal doses were calculated based on data from the ICRP Publications. The effective doses from ^{134}Cs and ^{137}Cs were estimated to be 61 μSv and 98 μ Sv, respectively. The sum of 159 μSv was lower than the total effective dose (310 μSv), from the inhalation and ingestion of natural radionuclides. The dose of ^{131}I was also reviewed referring to the UNSCEAR 2000 Report. The equivalent effective dose of ^{131}I was estimated to be 2.9 mSv, 18 times more than the amount of ^{134}Cs and ^{137}Cs. Therefore, it is considered that the earlier estimation of internal doses of ^{131}I is important in evaluating radiation injuries from a nuclear reactor accident.

Keywords Gamma spectrometer, ^{134}Cs, ^{137}Cs, Urine, Internal dose, Chernobyl Accident

CLC numbers X838, X591

1 Introduction

In the analysis of a nuclear accident emergency, rapid determination of the quantity of radioactive materials present in the human body is necessary for estimating the internal doses. Following that, corresponding measures could be taken, including decontamination of the radioactive materials and elimination enhancement of radionuclides from the human body.

Usually, a whole-body counter can be used to detect radionuclides directly and estimate internal doses. Besides, radioanalysis of urine can be done to obtain the contents of radionuclides in urine. Then, based on the excretion equations of radionuclides, the initial intake of the radionuclides can be calculated to estimate their internal doses according to the publications of the International Commission on Radiological Protection (ICRP).

In radioanalysis, the following instruments can be used: γ spectrometer, liquid scintillation counter, low background α/β counter, α spectrometer, inductively coupled plasma mass spectrometery (ICP-MS), and so on. Among these methods, high-resolution gamma spectroscopy provides fast, accurate, nondestructive isotopic analysis of radionuclides in bioassay samples and environmental samples. Therefore, it is often used in the activities of radiation emergency response.

In this study, using a Ge(Li) gamma spectrometer, a urine analysis was made for a visiting Chinese scholar, who worked at Kiev city (150 km from the Chernobyl Nuclear Power Plant) from late April to middle August in 1986 (just after the Chernobyl Accident). After 297 d, 351 d and 387 d of the accident, the contents of ^{134}Cs and ^{137}Cs in his urine samples were determined separately, and his internal doses from ^{134}Cs and ^{137}Cs were estimated.

Partially supported by National Natural Science Foundation of China (No.30370442).

*Corresponding author, E-mail: zhugy@shmu.edu.cn

Received date: 2006-05-18

In the early phase of the accident, ^{131}I was the major contributor to the internal dose, therefore, the dose of ^{131}I was also reviewed by referring to the UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) 2000 Report.[1,2]

2 Material and methods

2.1 Calibration of Ge(Li) gamma spectrometer

The detector of the S-80 Ge(Li) gamma spectrometer (Canberra Company, USA) was housed within a shield, which was constructed of "old lead" with a thickness of 10 cm. The lead was graded with 3 mm copper and 5 mm Perspex. The volume of the measuring cup was 660 mL. Its energy resolution and relative efficiency were 2.0 keV and 20%, respectively. The integrated background was 1.6 cps (50 keV – 2 MeV).

Standard solutions of ^{22}Na, ^{54}Mn, ^{57}Co, ^{60}Co, ^{65}Zn, ^{88}Y, ^{109}Cd, ^{133}Ba, ^{137}Cs, ^{210}Pb, and ^{241}Am from Shanghai Institute of Measurement and Testing Technology were used for energy calibration and efficiency calibration. From these radionuclides, the full energy peak efficiencies for energies of 46.5, 59.5, 88.0, 122.1, 136.5, 276.4, 302.8, 356.0, 383.8, 661.7, 834.8, 898.0, 1115.5, 1173.2, 1274.5, 1332.5, and 1836.1 keV were obtained. The energy efficiency calibration curve is shown in Fig.1.

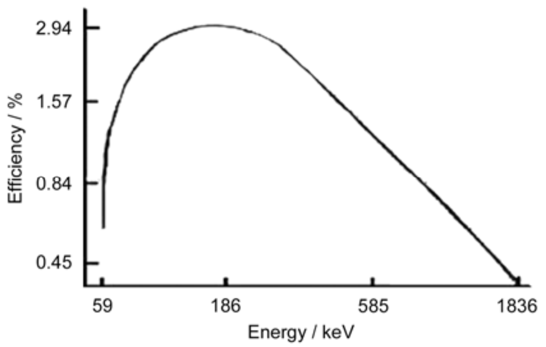

Fig.1 The energy efficiency calibration curve.

2.2 Determination of ^{134}Cs and ^{137}Cs in urine

To determine the ^{134}Cs and ^{137}Cs in the urine, the Ge(Li) γ spectrometer was used to measure the urine directly without an extensive sample preparation procedure. Twenty-four-hour urine was collected, followed by the transfer of 460 mL into the measuring cup to be counted in the γ spectrometer. Net peak area counts of the 602, 662, and 796 keV gamma rays emitted from ^{134}Cs and ^{137}Cs were used to calculate their respective activities.

3 Results and discussion

3.1 Results of ^{134}Cs and ^{137}Cs

The contents of ^{134}Cs and ^{137}Cs measured in the subject's urine are summarized in Table 1. The following fractional excretion equation[3] was used to calculate the excretion fraction of the day when the urine was collected:

$$Y_s(t) = 0.1e^{-0.693t} + 0.005e^{-0.006t}$$

The total excretion through urine was obtained by dividing the contents in urine by the fraction. And the fraction of total excretion by urine was 0.8.[4] Besides, the decay correction for ^{134}Cs was also considered. Thus, the initial intakes of ^{134}Cs and ^{137}Cs of this subject are estimated in Table 2.

Table 1 The contents of ^{134}Cs and ^{137}Cs in the subject's 24-hour urine

Days after the accident/d	Volume of urine /L	^{134}Cs /Bq•L^{-1}	^{137}Cs /Bq•·L^{-1}
297	1.51	1.47	3.21
351	1.63	0.64	2.53
387	1.75	0.38	1.59

Table 2 The estimated initial intakes of ^{134}Cs and ^{137}Cs for the subject

Days after the accident/d	Fraction of urinary excretion for Cs (Y_s)	Initial intake /Bq	
		^{134}Cs	^{137}Cs
297	8.415 × 10^{-4}	4332	7205
351	6.086 × 10^{-4}	2952	8462
387	4.904 × 10^{-4}	2402	7086
Average		3229	7584

For ^{134}Cs and ^{137}Cs, dose coefficients recommended by the ICRP Publication, 72[5] were 1.9 × 10^{-8} Sv•Bq^{-1} and 1.3 × 10^{-8} Sv•Bq^{-1}, respectively. The dose coefficient is the committed effective dose per unit intake of radioactive material into the body (Sv•Bq^{-1}).

On the basis of the average intake of ^{134}Cs and ^{137}Cs in Table 2, the committed effective doses from ^{134}Cs and ^{137}Cs are estimated to be 61 μSv and 98 μSv, respectively, with a total of 159 μSv. The value is lower than the world-averaged total effective dose (310 μSv) from the inhalation and ingestion of natural radionuclides. Of the 310 μSv, 170 μSv is from ^{40}K, and the other 140 μSv is from the long-lived radionuclides in uranium and thorium series.[6]

Without performing the elimination enhancement of radionuclides for the subject, the contents of ^{134}Cs and ^{137}Cs in his urine were below the minimum detection limit of the measuring system on Feb 11, 1989 (1022 d after the accident).

3.2 Dose review of ^{131}I

In the later phase of the Chernobyl Accident, ^{134}Cs and ^{137}Cs were the major contributors to health problems, but in the early phase of the accident, radioactive iodine played a major role in impacting human health. To estimate the internal dose for radioactive iodine, the initial intakes of ^{131}I were estimated from the intial intakes of ^{134}Cs and ^{137}Cs.

UNSCEAR 2000 Report[6] provided the data to estimate the principal radionuclides released in the Chernobyl Accident. According to the data, based on the ratio of ^{131}I to ^{134}Cs (33.4) and the ratio of ^{131}I to ^{137}Cs (19.9), as well as the evaluated intakes of ^{134}Cs (3229 Bq) and ^{137}Cs (7584 Bq), the intakes of ^{131}I were estimated to be 107849 Bq and 150922 Bq, respectively. Furthermore, based on the estimated average of ^{131}I intake (1.3×10^5 Bq) and the dose coefficient for ^{131}I (2.2×10^{-8} Sv•Bq^{-1}) [5], the effective dose from ^{131}I was estimated to be 2.9 mSv.

Among the total effective doses of 3.1 mSv from ^{134}Cs, ^{137}Cs, and ^{131}I, the internal dose from ^{131}I is 18 times higher than the sum of ^{134}Cs and ^{137}Cs. Therefore, the earlier estimation of internal doses of ^{131}I is important in evaluating the radiation injuries of a nuclear reactor accident.

Acknowlegment

The authors would like to thank Prof. WU Shuilong in the Shanghai Center for Diseases Control and Prof. ZHUO Weihai in the Institute of Radiation Medicine, Fudan University, for their help in the discussion and amendment of this article.

References

1 Maria G, Hon Fon L, Sandro B, *et al*. Arch Environ Health. 1998, **53**(5): 344-346.

2 Holgye Z, Maly M. Health Phys, 2002, **82**(4): 517-520.

3 ICRP Publication 10A. The assessment of internal contamination resulting from recurrent or prolonged uptakes, 1969.

4 ICRP Publication 10. Evalution of radiation doses to body tissues from internal contamination due to occupational exposure. Pergamon Press, 1967.

5 ICRP Publication. 72, Age-dependent doses to the members of the public from intake of radionuclides, Part 5, Compilation of ingestion and inhalation coefficients. Pergamon Press, 1996.

6 UNSCEAR 2000 Report. Sources and effects of ionizing radiation, United Nations, New York. Annex J: 519, 2000.