Journal of the Korean Nuclear Society
Volume 33, Number 2, pp.225~230, April, 2001

Determination of Trace Uranium in Human Hair by Nuclear Track Detection Technique

Yong Sam Chung, Jong Hwa Moon and Zinaida En
HANARO-Center, KAERI, Taejon, Korea
150 Dukjin-dong, Yusong-gu, Taejon 305-353, Korea
yschung@kaeri.re.kr
Seung Yeon Cho and Sang Hoon Kang
Yonsei University, Wonju, Korea
234 Maeji-ri Hungup-myun Wonju-si, Kangwon-do 227-701, Korea
Jae Ki Lee
Hanyang University
17 Haengdang-dong, Sungdong-gu, Seoul 133-791, Korea
(Received September 25, 2000)

Abstract

The aim of this study is to describe a usefulness of nuclear analytical technique in assessing and comparing the concentration levels through the analysis of uranium using human hair sample in the field of environment. A fission track detection technique was applied to determine the uranium concentration in human hair. Hair samples were collected from two groups of people - a) workers not dealing with uranium directly, and b) workers possibly contaminated with uranium. The concentration of ^{235}U for the first group varied from <1 to 39 ng/g and the second group can be estimated up to the level of μg/g. Radiographs of heavy-duty work samples contained high dense "hot spots" along a single hair. After washing in acetone and distilled water, external contamination was not totally removed. Insoluble uranium compounds were not completely washed out. The (n, f)-radiography technique, having high sensitivity, and capable of getting information on uranium content at each point of a single hair, is an excellent tool for environmental monitoring.

Key Words : nuclear track detection, radiography, uranium, human hair

Introduction

As hair has a property to absorb trace elements and to retain from its environmental conditions, it is considered to be an appropriate indicator of the internal status of the individual and of environmental pollution for heavy metals, for uranium particularly. Some investigators have claimed that concentrations of trace elements in hair may differ with respect to non-essentials due to differences in trace element intake or environmental exposure.[1-5] In addition, hair has some merits to be collected readily from individuals and to be handled easily. It has made many researchers to be interested in human hair as a biopsy material. So far it made a considerable amount of data on trace elements in the hair of normal healthy persons to be reported.[6-9]

Uranium, having isotopic abundance of 99.3 % ^{238}U and 0.7 % ^{235}U in nature, is a toxic and radioactive metal. The enriched uranium(3-5 % of ^{235}U) is mainly used for the fuel of nuclear reactors, and it can make unbalance in the natural isotopic abundance of uranium(ratio of $^{235}U/^{238}U$).

Fission track etching technique is useful for determining fissile materials, especially uranium.[10] Fission track technique coupled with radiography using thermal neutron of research reactor is suitable for detecting ^{235}U with a high sensitivity and a good selectivity directly. The detection limit is reported as to be up to $\sim 10^{-3}$ ng/g for ^{235}U and $\sim 10^{-4}$ μg/g for natural uranium.

In this study, fission track etching technique was applied for the determination of trace uranium in human hair samples for the identification of accumulation levels from subjects of two groups with working condition.

2. Experimental

2.1. Technique

The nuclear track technique is related to local analytical methods, capable of getting the surface distribution of the determined element. The basic principle of this method is follows ; uranium emits the fission products by nuclear reaction with thermal neutron and it impacts the detector which is in close contact with the sample and leaves latent tracks in the surface layer of the detector like LEXAN. So the location of tracks is very closely consistent to location of the determined element, which makes it possible to examine each local point of the sample interested. The flow diagram shown in Fig. 1 outlines the procedure of the track radiography technique.

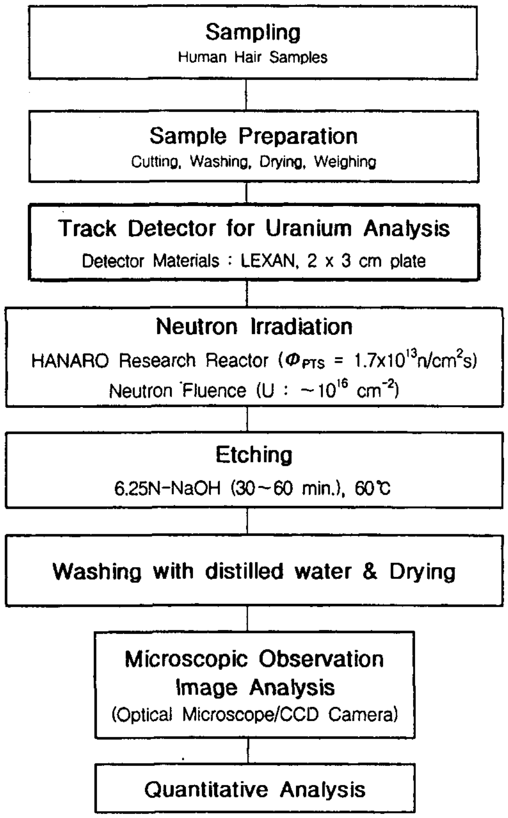


Fig. 1. Flow Diagram of Nuclear Track Technique for Uranium Analysis

2.2. Sampling

Hair samples were collected from subjects of two groups of people, ten samples from office and laboratory workers not dealing with uranium directly, and eight samples from workers related to uranium experiments. The samples were grouped into two, one is unwashed and other is washed. In accordance with the IAEA' s recommended method [1], washing of hair sample(about 2cm) was done with acetone and distilled water for decontamination. The samples were dried on filter paper at room temperature. Two or three of hair samples were put into a piece of LEXAN foil(2 × 3 cm) for neutron irradiation.

2.3. Neutron Irradiation

A plastic film, LEXAN, was used for the detection of fission fragments from the ^{235}U(n, f)-reaction. Irradiation was performed at the HANARO reactor in the pneumatic transfer tube (NAA #1) with a thermal neutron flux of $\sim 1.7 \times 10^{13} cm^{-2} sec^{-1}$ with a Cd ratio of $\sim$200, for 10 min.

2.4. Chemical Etching

After exposure, the LEXAN foils were detached from the sample and etched in a 6.25 N NaOH solution for 60 min at 60℃. Chemical etching enables transformation of latent images to tracks visible in optical microscope. Latent tracks can be considered as radiation damage zones. It is known that the etching rate in the immediate environment of the radiation damage is much higher than the bulk etching rate in the undamaged region. This effect can be explained by the fact that such a defect leads to weakening atomic or molecular bonds, and the removal of atoms from the damage is a more probable process than from undamaged regions. After etching, the detectors were thoroughly washed in distilled water and dried.

2.4. Image Analysis

Radiographs of etching tracks is analyzed by the observation of image with optical microscope, the image capture by digitizing and quantitative calculation. The magnification used for counting of track was about 500. The images were captured with a CCD camera and analyzed with Scion Image software.

2.5. Quantitative Calculation

When a detector is in contact with a sample containing uranium in 2π geometry, the true track density produced by the fission fragments is a measure of the content of the material fissile under the conditions of irradiation. In the absence of other fissile materials and using a thermal neutron flux, the track density is proportional to the concentration of ^{235}U. The concentration of ^{235}U was calculated by the following formula:

Table 1. Concentration of ^{235}U in the Hair of the First Group

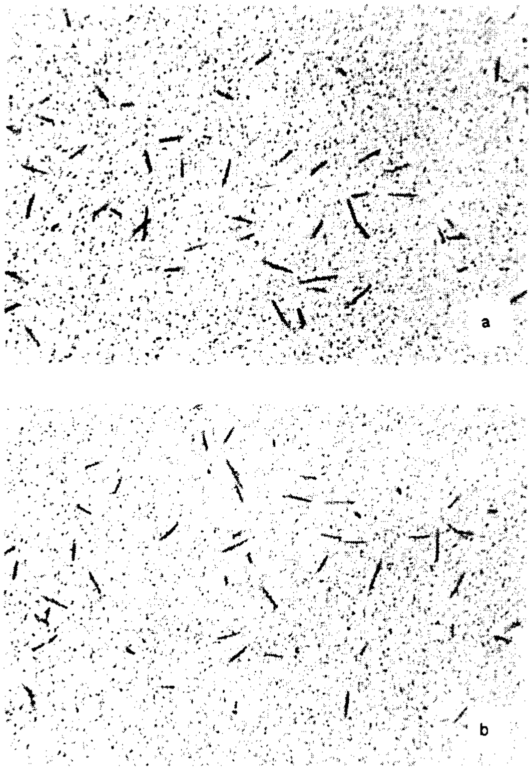
Sample number	Concentration of ^{235}U, ng/g
1-1	<0.1
1-2	26.4 ± 2.0
1-3	<0.1
1-4	38.9 ± 3.5
1-5	<1
1-6	33.7 ± 5.8
1-7	17.0 ± 1.5
1-8	22.0 ± 1.6
1-9	16.0 ± 1.0
1-10	<0.1

$$C_U = 2A_U\rho_v / (N_0\, \Phi \sigma R_{eff})\, \eta \qquad (1)$$

Where, C_U = concentration of ^{235}U, g/g
A_U = Atomic mass, g
ρ_U = fission fragment track density, cm^{-2}
N_0 = Avogadro' s number
Φ = Thermal neutron fluence, cm^{-2}
σ = differential cross section of ^{235}U (n, f)-reaction, cm^2
η = detection efficiency
R_{eff} = effective range of fission fragments in a sample material, $g.cm^{-2}$.

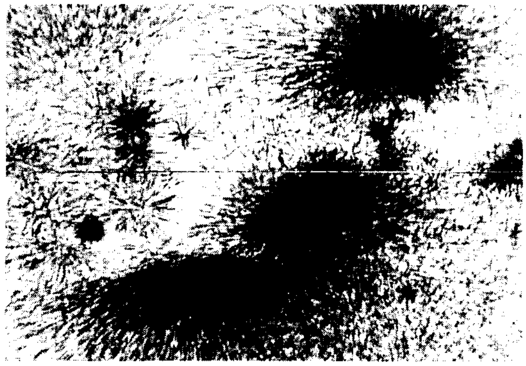
3. Results and Discussion

The uranium concentration in the hair of the first group is shown in Table 1. The concentration

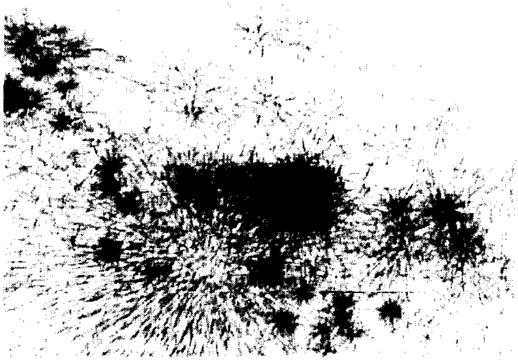


25㎛

Fig. 2. (n, f)-radiograph of the Hair Sample #9 of Group 1 (a) Unwashed, (b) Washed Neutron Fluence : ~ 10^{16} cm^{-2}. $C_{U\text{-}235}$: ~ 16 ng/g



25㎛



50㎛

Fig. 3. (n, f)-radiograph of a Contaminated Hair Sample (F4, unwashed) Neutron fluence : ~ 10^{16} cm^{-2}

of ^{235}U for the first group was varied from <1 to 39 ng/g. The fission track radiograph of the sample #9 is demonstrated in Fig. 2. There is no difference between the washed sample and unwashed sample. It is suggested that there is no exposure of uranium from an external environment.

Fission track distributions for the second group samples were characterized by non-uniformity with significant amounts of "stars", so-called "hot spots" of different densities and dimensions along a single hair. It is assumed that the track stars were formed by uranium particles deposited intensively on the hair surface from the environment. Such distributions of uranium fission tracks can be seen in Fig. 3, in which there are two radiograph of the most contaminated sample(F4, unwashed) with different magnifications. After washing the sample in acetone and distilled water, a significant amount of uranium remained on the hair surface, which is clearly seen in Fig. 4. Non-uniform track distribution and the star forms indicate that contamination was not internal, and uranium has deposited on the hair surface from the environment. The concentration of ^{235}U for the second group can be estimated up to the level of μg/g with reference to the analytical results of

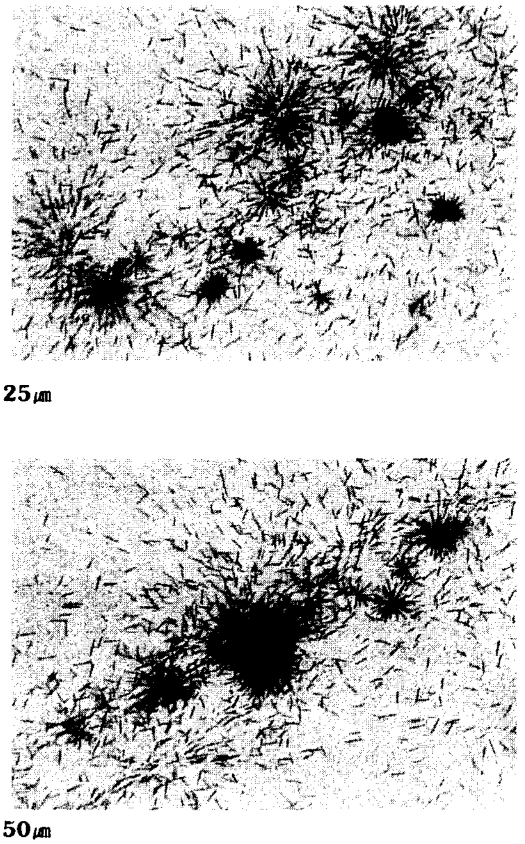


Fig. 4. (n, f)-radiograph of a Contaminated Hair Sample (F4, washed)
Neutron fluence : ~ 10^{16} cm^{-2}

uranium in the same samples by neutron activation analysis.[4,9]

4. Conclusions

The experiments carried out have proved that human hair can serve as an indicator of environmental pollution, and the track etch radiography technique can directly provide information on contamination character. The (n, f)- radiography, having high sensitivity and selectivity, and capable of giving the distribution of uranium along a single hair or other analyzed object, is an excellent tool for environmental monitoring.

Acknowledgement

This project has been carried out under the Nuclear Research and Developement Program by MOST

References

1. S. Ohmori and M. Hirata, "Determination of bromine contents in blood and hair of workers exposed to methyle bromide by radioactivation analysis method", 24, 119 (1982).
2. J. Akashi, I. Fukushima, A. Imahori, S. Shiobara, Y. Takahashi and K. Tomura, "Multielement analysis of the hair of mining industry workers", *J. Radioanal. Nucl.* Chem., **68**, 59 (1982).
3. I. Obrusnik, O. Skrivanek, M. Umlaufova and V. Hovorka, "Neutron activation analysis of neonate and maternal hair sampled in areas with different levels of pollution", *J. Radioanal. Nucl.* Chem., Articles, **89**, 561 (1985).
4. Y. Katayama and N. Ishida, "Determination of antimony in nail and hair by thermal neutron activation analysis", *Radioisotopes*, **36**, 103 (1987).
5. S. Y. Cho, O. D. Awh and Y. S. Chung, "Trace element exposure in human by instrumental neutron activation analysis of hair", *J. Radioanal. Nucl.* Chem., **217**, 1, 107 (1997).
6. Y. S. Ryabukhin, "Activation analysis of hair as an indicator of contamination of man by environmental trace element pollution", IAEA/RL/50, International Atomic Energy Agency, Vienna (1978).
7. Y. S. Ryabukhin, "Nuclear-based methods for

the analysis of trace element pollutions in human hair", *J. Radioanal. Nucl.* Chem., **60**, 7 (1980).

8. M. Yukawa, M. Suzuki-Yasumoto and S. Tanaka, "The variation of trace element concentration in human hair ; the trace element profile in human long hair by sectional analysis using neutron activation analysis", *Sci. Total Environ.*, **34**, 41 (1984).
9. S. Y. Cho, S. G. Jang and Y. S. Chung, "Human Hair Identification by Instrumental Neutron Activation Analysis", *J. Radioanal. Nucl.* Chem. Letters, **229**,1-2, 143 (1998).
10. S. Amiel, " Nondestructive Activation Analysis", Studies in Analytical Chemistry, Elsevier Sci. Pub. Co., 88 (1981).