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Determination of Gross-β and γ-Ray Activity Concentrations of Human Tooth

-치아의 전베타 농도 및 감마선 방사능 평가-

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— Abstract —

The γ-ray concentration and gross-β activity by age group were measured in the teeth of males and females of the domestic residents. They were divided into 7 age groups from 10s to the age of 70s. The gross-β activity concentration was measured by using the Tennelec XLB measuring instrument filled with P10 gas (argon 90%, methane 10%). The γ-ray was measured through the γ-ray spectroscopic analytical method by using the high purity germanium (HPGe) radiation detector. The range of gross-β activity concentration was measured 0.089 to 0.32 Bq/kg in females and 0.13 to 0.26 Bq/kg in males. From the γ-ray spectroscopic analysis of the teeth, the natural radioactive isotopes of ^{40}K, ^{208}Tl, ^{228}Ac and ^{234}Th were detected and their measured γ-ray activity concentrations were found to be 20.7, 21.9, 3.88 and 5.24 Bq/kg, respectively.

Key Words : Gross-β, γ-ray activity, Human tooth

Ⅰ. Introduction

People are exposed to natural radiations generated constantly from the earth's surface or space, artificial radiation from nuclear weapon experiments of the past and recent accident at a nuclear power plant. Exposure to natural radiation can be divided into 'external irradiation' caused by the radioisotope existence in the nature and 'internal irradiation' caused by the radioisotope contained in human body. The natural radiation varies, depending upon the region and the environment, and it is reported that approximately 83% of the annual exposed dose of ordinary people is attributed to natural radiation[1)].

As human beings live in the nature, radioisotope is included in the components that make up the human body and can cause internal irradiation. The type and amount of radioisotope in the human body are also affected by the nature and the region in which the people live. Aghamiri[2)], Ramachandran et al.[3,4)] and Almayahi[5)] conducted a study on the radioactivity concentration in different regions with high natural

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radioactivity concentration, such as Brazil, India and Iran, and investigated the effects of such radiation on the human body. Meanwhile, artificial radiation is attributed to nuclear weapon experiments of the past or accidents at nuclear power plants. In order to evaluate the impact on the human body, Kulev et al.[6] and Darchuk[7] reported his study on the internal radiation concentration in the children born in the region on Chernobyl that suffered a catastrophic explosion of nuclear power plant in 1986. Yamamoto et al.[4] conducted a study of the concentration of ^{226}Ra radioisotope that was substituted for calcium in the teeth structure of human body. Söğütet[8] also reported gross alpha and gross beta activity concentrations in human tooth. In particular, there has been a heightened interest in the evaluation of the impact of artificial radiation since the meltdown at the Fukushima nuclear power plant in 2011, which was the worst-ever nuclear power disaster.

The environmental radiation level needs to be monitored routinely to quantitatively evaluate the effects of artificial radiation caused by accident, etc. In this study, we measured the radioisotope contained in the teeth of Korean people through γ-ray spectroscopy method, and evaluated the gross-β activity concentration in the teeth based on gender and their age.

Ⅱ. Materials and Methods

The samples were collected from the teeth extracted from males and females aged between 10 and 80 at dental clinics located in Daegu, Korea. All studied samples were divided into 7 groups according to their age such as: 10s, 20s, 30s, 40s, 50s, 60s and 70s. For each age groups, we collected the samples from above 50 persons. The selected teeth samples were heated in an electric furnace for 48 hours at 400℃ after being washed. The heated teeth samples were pulverized to prevent self-absorption during the measurement of gross-β activity, and only the particles with the size of 75 μm or less were selected by using the fine sieve (#200). The size of hole of the fine sieve mesh is about 75 μm. To prepare the samples for the measurement of gross-β activity, each of the selected samples was quantified by 200 mg and spread as thinly as possible on the 2-inch stainless steel vessel to minimize the self-absorption. Meanwhile, the samples for γ-ray activity measurement were obtained by heating the teeth from all ages, regardless of the age group, and pulverizing them. Then, the pulverized teeth were put into U8 vial through quantification. In this study, gross-β measurement system (Tennelec XLB, Canberra Inc.) filled with P10 gas (Argon 90%, methane 10%) was used for the measurement of gross-β, and the operating voltage was selected as 1,540 V.

The high purity Ge Detector (HPGe) (GC3019-7500SL) was used for the γ-ray spectroscopic analysis. The results of measurement were analyzed by using a radioisotope analysis program: APTEC ver. 7.04.00.03, Canberra Co.

The energy, radiation detection efficiency and energy resolution calibration were performed by using the HPGe detector, the standard source manufactured by the Korea Research Institute of Standards and Science (KRISS).

After the calibration, the relative efficiency of the detector was found to be 33% with the energy resolution of 1.79 keV at 1.33 MeV γ-rays. The measurement was conducted with the applied voltage of 2,500 V, a coarse gain of 10, fine gain of 0.8, and pulse shaping time of 6 μs.

Each samples were measured 3 times for the duration of 1,800 seconds for gross-β activity measurement. Similarly the background measurement was also performed 3 times and for the duration of 1,800 seconds. The measured value of the samples was determined based on the detection efficiency calibration curve corrected with standard source, and was determined with the radioactivity concentration per unit mass of the samples.

Ⅲ. Results and Discussion

Fig. 1 presents the γ-ray wave spectrum measured with the samples of the teeth. The natural radioisotope contained in the samples and their radioactivity can be determined by comparing the γ-ray energy of the known radioisotope after converting the position of the peaks shown in Fig. 1 through the calibration of the energy and detection efficiency. Table 1 and Fig. 2 shows the radioisotopes in the teeth samples measured by using HPGe detector using γ-ray spectroscopy method and the results of radioisotope concentration analysis. As result, only a minute quantity of natural radioisotopes of ^{235}U, ^{238}U and ^{232}Th series were detected, but, some artificial radioisotopes were not detected such as ^{137}Cs, ^{60}Co, ^{90}Sr etc. Specially, ^{90}Sr very important artificial radioisotope because, strontium is accumulated in the human bone. Detected ^{208}Tl, ^{212}Pb and ^{228}Ac daughter radioisotopes are in Thorium-series and ^{214}Bi, ^{234}Th are in Uranium-series. In Table 1, there are no statistically significant differences for correlations between concentrations of radioisotopes. In the measured samples, ^{40}K and ^{208}Tl radioisotopes with a highest γ-ray activity concentration of 20.7 Bq/kg and 21.9 Bq/kg, respectively were observed.

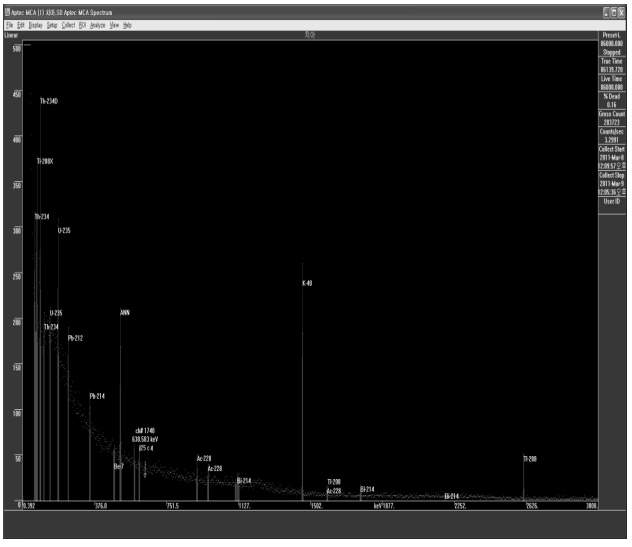


Fig. 1 Measured gamma spectrum by HPGe of a teeth sample

Table 1 Radioactivity concentrations in the teeth samples measured by using γ-ray spectroscopic analytical method

Radioisotopes	Activity (Bq/kg)	MDA (Bq/kg)
^{40}K	20.7	7.35
^{208}Tl	21.9	8.45
^{212}Pb	0.27	0.04
^{214}Bi	0.43	0.21
^{228}Ac	3.88	1.83
^{234}Th	5.24	0.15

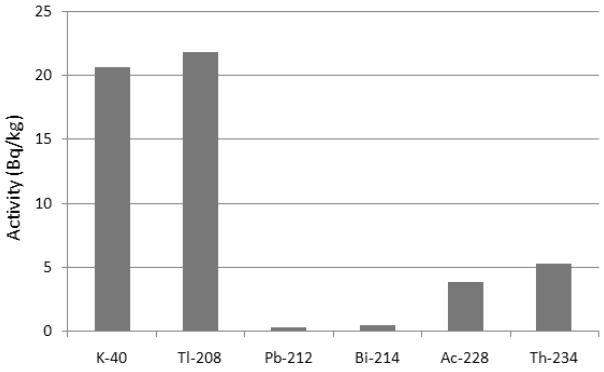
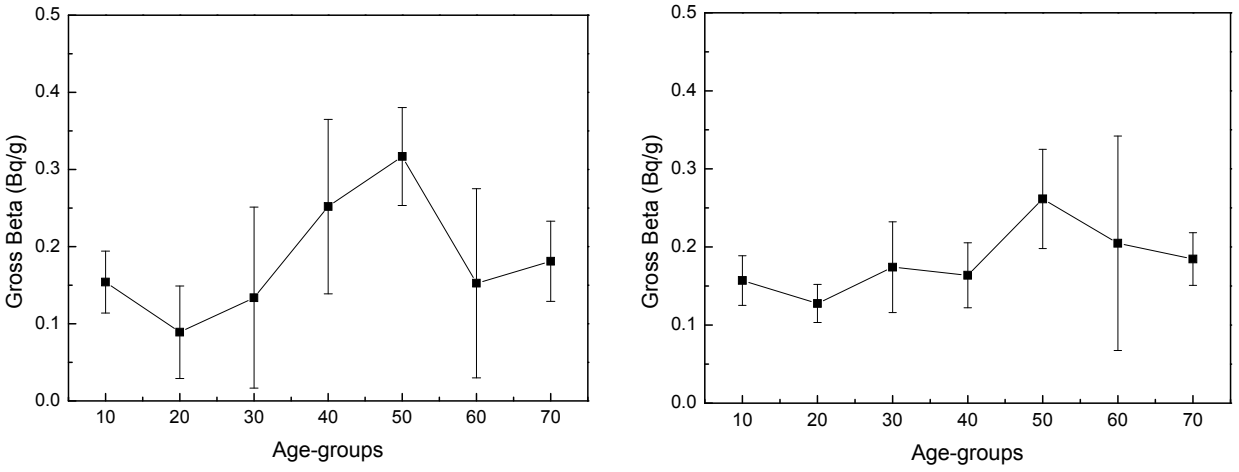


Fig. 2 Radioactivity concentrations in teeth samples measured by using γ-ray spectroscopic analytical method

Fig. 3 presents the gross-β activity concentration in the teeth samples obtained from the 7 age groups of males and females in this study. The range of gross-β activity concentration was 0.089 to 0.32 Bq/kg for females and 0.13 to 0.26 Bq/kg for males. Although a gross-β activity concentration was slightly higher in the male as compared to female, the difference was found to be insignificant. Sogut et al.[6] reported the gross-β activity concentration in the teeth samples of the males and females living in Turkey as 0.01 to 1.17 Bq/kg and 0.071 to 0.204 Bq/kg, respectively. Both sexes in their 50s showed the highest gross-β activity concentration level which was attributed to the fact that the density of the bone begins to decrease when human beings reach the age of approximately 50. Concentration of gross-β in human body is dependent on the regional concentration of gross-β. In 2012, the concentration of gross beta of rain fall in Daegu city was about 0.103



(a) Females (b) Males

Fig. 3 Gross-β activity concentration in males and females by age groups

Bq/kg[9]. Measured concentration of gross-β in tooth is higher than that of water because of high bone density.

Ⅳ. Conclusion

The concentrations of radioisotopes and gross-β activity in the teeth of some Korean males and females were analyzed by using HPGe detector and the low back β counter. Natural background radioisotopes were detected such as of ^{40}K and ^{208}Tl, except artificial radioisotopes. And, the range of gross-β activity concentration was 0.089 to 0.32 Bq/kg in females and 0.13 to 0.26 Bq/kg in males, respectively. The gross-β activity concentration was the highest in both males and females in their 50s. In 1990, Mangano et. al. studied the ^{90}Sr concentration in teeth of peoples who lived near nuclear power plants. They found that the average ^{90}Sr conentration was rose 48.5% for persons born in the late 1990s compared to those born in the late 1980s[10]. The results of this study will provide the foundation for the comparison based on the standard radiation level of the human body before the radiation leakage such as Mangano' results.

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•국문초록

치아의 전베타 농도 및 감마선 방사능 평가

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10세에서 70세까지 국내 남녀를 7개 연령대별 그룹으로 구분한 후, 치아의 감마선 농도와 각 그룹별 전β 방사능 농도를 측정하였다. 전β 농도는 P10가스(아르곤 90%, 메탄 10%)를 충진한 Tennelec XLB 측정기로 측정하였으며, 감마선은 고순도 게르마늄 검출기를 사용하여 감마선분광분석법으로 측정하였다. 본 실험에서 측정된 여성의 전β 방사능 농도범위는 0.089~0.32 Bq/kg이었으며, 남성의 전β 방사능 농도범위는 0.13~0.26 Bq/kg이었다. 치아의 감마선분광분석 결과 자연방사성동위원소인 ^{40}K, ^{208}Tl, ^{228}Ac 및 ^{234}Th가 검출되었으며, 측정된 감마선 방사선 농도는 각각 20.7, 21.9 3.88 및 5.24 Bq/kg 이었다. 본 연구 결과는 향후 후쿠시마 원전사고 등 불의의 방사선 누출 사고 등에 대비하여 정상 환경에서의 인체의 치아에 축적된 방사능 준위 데이터로 활용할 수 있을 것으로 사려된다.

중심 단어 : 전베타방사능, 감마 방사능, 치아