ANALYSIS OF THE NATURAL RADIOACTIVITY CONCENTRATIONS OF THE FINE DUST SAMPLES COLLECTED JEJU ISLAND, KOREA AND THE ANNUAL EFFECTIVE RADIATION DOSE BY INHALATION

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I. INTRODUCTION

The Gosan area in Jeju Island, South Korea serves as a natural background site for characterizing the air pollution in Korean peninsula since the atmosphere in the area is relatively very little affected by artificial airborne matters. Chemical composition analyses have usually been conducted for the atmospheric aerosols collected at the site. In this study, we have measured, using the ICP-DRC-MS, radioactivity concentrations of ^{40}K, ^{232}Th and ^{238}U contained in the atmospheric PM_{10} aerosols which were collected at the Gosan during the year of 2014.

II. MATERIALS AND METHODS

II.A. Collection of atmospheric aerosols

Air sampling for aerosols was conducted at the Gosan (33°17′N, 126°10′E), which is located on the seashore hill of 72 m above sea level at the western edge of Jeju Island, Korea. The samples have been collected using PM_{10} sampler at 24 hour basis with every 3 day intervals from January to December of 2014. On collecting samples, the air flow rate was kept to about 16.7 L/min, and total air flow was calculated from the flow rate and running time.

II.B. Sample Analysis

For the analysis of PM_{10} elemental species, the aerosol samples were decomposed with acids using a microwave digestion system 10 mL acid solution (5.55% HNO_3/16.75% HCl). The vessel was heated at 180℃ for 15 minutes with 1000 W microwave radiation to digest the PM_{10} aerosols.[1] The number of elements determined by ICP-DRC-MS instruments was 3 species such as ^{39}K, ^{232}Th and ^{238}U.

The radioactivity concentrations of the isotopes ^{40}K, ^{232}Th and ^{238}U in the collected fine dust were calculated using the following Eq. (1) (Ref. 2):

$$A_i = \frac{\ln 2}{T_{1/2}} \times \frac{\rho_i \times m_e}{M_i} \times N \qquad (1)$$

where A_i, $T_{1/2}$, ρ_i, m_e, M_i, and N are the radioactivity concentration (Bq/m^3), half-life time (s) of isotope i (^{40}K; 1.28×10^9 y, ^{238}U; 4.468×10^9 y, ^{232}Th; 1.405×10^{10} y), isotopic ratio (natural abundance) of isotope i, the mass concentration of element e corresponding to isotope i (g/m^3)), atomic mass (g/mol), and the Avogadro's number (6.022×10^{23} mol^{-1}), respectively. The isotopic ratios for ^{40}K, ^{238}U and ^{232}Th were 0.000117, 0.99275 and 1.0, respectively.

The inhalation annual effective radiation dose ($E_{h,i}$) due to fine dust was calculated using the following Eq. (2) (Ref. 3)

$$E_{h,i} = A_i \times B \times d_{h,i} (1 - F_0 + F_0 F_r) \qquad (2)$$

where A_i is the integrated activity concentration of radionuclide i associated with fine dust in outdoor air (Bq/m^3), B is the breathing rate (m^3/y), $d_{h,i}$ is the committed dose per unit intake from inhalation or effective dose coefficient (Sv/Bq), F_o is the indoor occupancy factor and F_r is the ratio of indoor to outdoor air concentration.

III. RESULTS AND DISCUSSION

As an alternative method, we have measured, using the ICP-DRC-MS, radioactivity concentrations of ^{40}K, ^{232}Th and ^{238}U contained in the atmospheric PM_{10} aerosols which were collected at the Gosan during the year of 2014. A total of 115 samples have been analyzed, of which 5 samples are those collected during Asian Dust days, 47 samples collected during normal weather days (no-event days), and the remaining samples collected during the days of haze and fog-mist. The mean

mass concentration of PM_{10} was 47.31 μg/m^3. During the study period, the mean concentrations of ^{40}K, ^{232}Th and ^{238}U were 0.56, 1.02 and 0.53 mg/kg, respectively. The mean active concentrations of ^{40}K, ^{232}Th and ^{238}U during normal days are 7.89, 0.25 and 0.30 μBq/m^3, respectively. The ^{232}Th/^{238}U activity concentration ratio of PM_{10} was 0.830. The radioactivity concentrations of those isotopes were analyzed by atmospheric phenomenon (Asian Dust, Haze, Fog-Mist and Non-Event). During Asian Dust periods (5 samples), the radioactive concentrations of ^{40}K, ^{232}Th and ^{238}U were 40.894, 1.466 and 1.367 μBq/m^3, respectively. And these were highly as 6.94, 8.57 and 7.05 times, respectively, compared to the non-event periods (47 samples). The ^{232}Th/^{238}U ratio of Asian Dust was 1.073, which was higher than those of other atmospheric phenomenon (0.707~0.882).

Table 1. Airborne PM_{10} concentrations, the associated ^{40}K, ^{232}Th and ^{238}U activity concentrations (μBq/m^3) and activity ratio by atmospheric phenomenon at Gosan site in Jeju Island, 2014

Atmospheric Phenomenon	^{40}K (μBq/m^3)	^{232}Th (μBq/m^3)	^{238}U (μBq/m^3)	^{232}Th/^{40}K	^{238}U/^{40}K	^{232}Th/^{238}U
Asian Dust (*n*=5)	40.89±23.20	1.47±0.72	1.37±0.55	0.036	0.033	1.073
Haze (*n*=6)	18.29±17.73	0.50±0.40	0.50±0.44	0.028	0.039	0.707
Fog-Mist (*n*=57)	5.58±6.24	0.17±0.23	0.24±0.24	0.031	0.043	0.715
Non-Event (*n*=47)	5.85±4.67	0.17±0.15	0.19±0.16	0.029	0.033	0.882
All (*n*=115)	7.89±10.89	0.25±0.37	0.30±0.35	0.031	0.037	0.830

We are analyzing five-day backward trajectories of the air inflow into the Gosan site using the HYSPLIT4 model. The frequency of air inflow into the Gosan site is 34.84 % from Sector I (China continent), 22.58 % from Sector II (Korean peninsula), 11.61 % from Sector III (Japan) and 5.16 % from Sector IV (North Pacific Ocean) during normal days. During Asian dust days, the air inflow is dominated from Sector I. As a result of analyzing the air volume, the concentration ratio of ^{238}U/^{40}K was 0.036 and ^{232}Th/^{40}K was 0.032 in Sector 1. The concentration ratio of ^{232}Th/^{238}U was measured as 0.886.

The $E_{h,i}$ (default mode F) to the public due to natural isotopes of the airborne PM_{10} was in the range 17.56 ~ 83.74 nSv/y, depending on the age group. The $E_{h,i}$ (15 y, male) of Asian Dust was 498.84 nSv/y, which was 8.58 times higher than those of the Non-Event dust (58.17 nSv/y).

IV. CONCLUSIONS

The atmospheric PM_{10} aerosols (115 samples) were collected at Gosan of Jeju Island, which is one of the natural background sites of Korea, during the year of 2014. This study analyzed using ICP-DRC-MS the concentrations of potassium, thorium and uranium, and evaluated the annual effective dose by breathing from the results. The mean mass concentration of PM_{10} was 47.308 μg/m^3. The mean radioactive concentrations of ^{40}K, ^{232}Th and ^{238}U were 7.89, 0.25 and 0.30 μBq/m^3, respectively. The ^{232}Th/^{238}U activity concentration ratio of PM_{10} was 0.830. The ^{232}Th/^{238}U ratio during Asian Dust days is 1.073, which is higher than those in other atmospheric conditions. During Asian dust days, the air inflow is dominated from Sector I (China continent). The concentration ratio of ^{232}Th/^{238}U was 0.886 in Sector 1. In this study, the ratio of each nuclide was compared according to the inflow route. As a result, it was confirmed that the ratio of each nuclide was slightly different according to the inflow route. It is expected that this will be a preliminary data for analyzing the sources and various weather phenomena of fine dust on the peninsula.

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