Measurement of Radioactivity in Dust in the Air using Gamma-ray Spectroscopic Analysis

Sudi Ariyanto , Ko Noguchi
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Abstrak

Pengukuran Radioaktif di udara dilakukan dengan menggunakan spektrometri gamma. Kertas penyaring He-40T ditata pada kolektor udara setinggi 0.5-1.5 meter dari tanah. Pengumpulan udara dilakukan selama 1.5 jam dan kecepatan alir rata-rata udara yang melalui penyaring diukur. Penyaring kemudian di letakkan 3 em dari detektor HPGe . Pengukuran radioaktifpada kertas saring menggunakan sistem MCA. Pengukuran dilakukan selama 3000 detik. Data eksperimen menunjukkan bahwa konsentrasi radioaktif Pb-212 di udara pada rentang 6.11 e-8-17.2 *e-8Bq/cm*^{3}.

Abstract

Experiment on measurement of radioactivity in the air using gamma spectrometry has been done. He-40T filter paper was set-up on the air collector (stapler) at 0.5-1.5 meters from the ground. Duration of air collection was set for 1.5 hours and flow rate of the air passing through the filter was measured. The filter, then, was put at 3 ern from a HPGe detector. Measurement of radioactive in the filter used a MCA system. The system was set at 3000 seconds for the counting time. Data obtained from the experiment have shown that radioactive concentration ofPb-212 in the air was in the range of 6.11 e·g -17.2 e-^{g}Bq/crrr'.

Introduction

Generally it is known that there are two main radiation according to its occurrence: man-made radiation and natural radiation. Due to the existence of natural radiation, people are always exposed by radiation. For radiation workers, the existence of natural radiation gives addition radiation doses besides of the dose from hand-made radiation. In nuclear facility, the working environment, especially air, is regularly monitored.

The purpose of air contamination monitoring in working environment is to confirm that the works are executed under an adequate condition in term of radiation safety, to prevent workers skin contamination and internal exposure by detecting unexpected air also estimating the contamination. In addition, the purpose includes to estimate maximum radioactivity inhaled into body due to the monitoring results, and to obtain information for planning on internal exposure monitoring and the protection.

The origin of radioisotopes in the air is due to the presence of long-lived nuclides uranium and thorium under the ground and also from cosmic radiation. The decays of uranium produces successive decays that forms uranium series. Thorium decay also produces thorium decay series.

Successive Radioactive Decay

Consider there is a successive decay of radionuclides as follows:

$$N_I \sim N_2 \sim N_J$$

$$\frac{dN_1}{dt} = -AN_1$$

$$\frac{dN_2}{dt} = {}_1N_{"1122} - A_2N_2$$

$$\frac{dN_J}{dt} = A_2N_2 - AJN_J$$

$$N_1 = N_{10}e^{-\lambda_1 t}$$

$$N_2 = N_{10}\frac{\lambda_1}{\lambda_2-\lambda_1}\left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)$$

$$N_3 = N_{10}\lambda_1\lambda_2 \Big([illegible] + [illegible] + [illegible] \Big)$$

If the radioactive achieve equlibrium between the nuclides and its short half-live daughter in the air, then radioactivity of the daughter nuclides is constant and it can be expresses by

$$N_1\lambda_1 = N_2\lambda_2 = N_3\lambda_3 = \ldots\ldots = N_i\lambda_i$$

The number of daugther atoms at time t after sampling can be calculated by the following relationship:

1st daughter nuclide: $N_{10}\, e^{-\lambda_1 t}$
2nd daughter nuclide: $N_{20}\, e^{-\lambda_2 t} + N_{2,1}$
3rd daughter nuclide: $N_{30}\, e^{-\lambda_3 t} + N_{3,2} + N_{3,1}$

If the dust collecting time is longer than 3 times of the half-life of the nuclide, the radioactivity of these nuclides become constant and the concentration in the air can be expressed as follows:

$$C_s = \frac{0.693}{T_{1/2}} \cdot \frac{1}{F\cdot\frac{\eta_c}{100}\cdot\frac{\eta_m}{100}} \cdot \frac{1}{60} \cdot \frac{1}{1-e^{-\frac{0.693}{T_{1/2}}T_c}} \cdot \frac{S_f}{S}$$

where:
F : true average flow rate of air (l/min)
$T_{1/2}$: half life of the activity (min)
Tc : collection time (min)
T' : lapsed time after the sampling
η_m : counting efficiency (%)
η_c : collection efficiency of filter paper (%)
Sf : total collection area of filter paper (cm^2)
S : Collection area of filter paper measured (cm^2)

Ao can be calculated by taking into account correction of counting time,

$$A = \frac{\lambda n_0}{(1-e^{-\lambda t_c})\cdot I_E \cdot \varepsilon}$$

A : radioactivity at the beginning of counting
λ : decay constant of the nuclide
no: counts at intended peak
ε : counting efficiency for energy of gamma - ray
I_E: emission rate per decay
tc: counting time.

Experiment
Procedure of energy calibration
1. Open the cover of sample chamber and put a composite sample (Ba-133, Co-60, Cs-137), close the cover
2. Set counting time of MCA to be 300 sec and start counting
3. Start up gamma spectrometry software to get the data from the MCA
4. Store the result in the computer

Procedure of counting efficiency energy calibration:

1. Open the cover of sample chamber and put Eu-152, close the cover
2. Set counting time of MCA to be 300 sec and start counting
3. Start up gamma spectrometry software to get the data from the MCA and then let it calculating calibration equation
4. Store the result in the computer

Procedure of dust sampling

1. On the surface of the HE-40T filter paper draw a circle of 50mm in diameter. Set the filter on the air collector (Stapler)
2. Set the Stapler at the measuring point of 0.5 to 1.5m high from the floor, and switch the power on. Record the time of power on and the indicated flow rate of air.
3. After 1.5 hours operation of the Stapler, read and record the flow rate again. Switch the power off and record the time.
4. Remove the filter paper out and cut the circle off, and set it in stainless steel dish.

Procedure of sample counting (0

I. Open the cover of sample chamber and put the sample at a distance of 3 cm from the detector
2. Set counting time of MCA to 3000 sec and start counting
3. Start up gamma spectrometry software to get the data from the MCA
4. Print the result.

Procedure of sample counting (10

1. Open the cover of sample chamber and put the sample at a distance of 3 cm from the detector
2. Set counting time ofMCA to 180 sec and start counting
3. Start up gamma spectrometry software to get the data from the MCA
4. Print the result
5. Plot the data of each element on a graph paper and predict the number of element at the end of counting
6. Calculate concentration

Result

Counting Efficiency

Figure 1 shows data obtained for measuring the detector efficiency. From this figure it is found that the counting efficiency as a function of energy can be expressed by below relationship:

$$Tlc = 3.6393\ E\cdot O.8438$$

Table below shows the experiment condition for the 1st (left) and 2nd (rigth) measurement. .

Location	Gamma counting room # I
bate	23 August,2001
Irime	b9:47-11:17
~ollecting time	~Omin
Pump speed	625 liter/min
Start of counting	11:35
~ounting time	~OOOs

!.--ocation	~amma counting room # I
LOate	~3 August,200 I
trime	b9:46 - 11:16
~ollecting time	90 min
Pump speed	600 liter/min
Start of counting	12:14
bounting time	3000 s

The result of 1st measurement can be seen in Table .. while for 2nd measurement in Table
a.

Element	Energy, keY	counts
IPb-212	~38.66	145 ± I I
IPb-214	1351.94	1500± 28
lBi-214	1609.37	1706± 29

Element	Acs, Bq	C, Bq/crrr'
Pb-212	~.21±0.12	6.11 E-08 ± 2.22E-OQ
Pb-214	~3.51± 1.78	~.45E-06 ± l.30E-07
Bi-214	~4.62 ± 3.58	1.56E-06 ± 1.25E-01

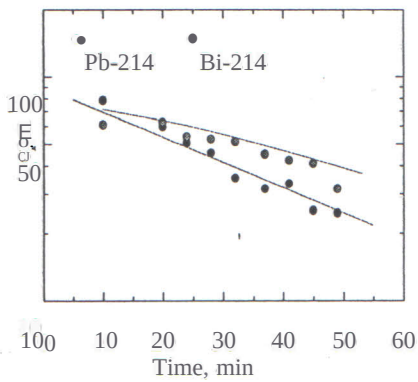
b.

Element	Energy, keY	counts
IPb-212	1238.66	[84 ± 12
IPb-214	1351.94	1612±32
lBi-214	1609.37	895 ± 34

Element	Acs, Bq	C, BQ/cm]
Pb-212	8.51±0.31	1.72E-07 ± 6.22E-09
Pb-214	*41.02±2.p*	4.72E-06 ± 2.55E-07
Bi-214	56.56 ± 4.55	2.48E-06 ± 1.99E-07

The total concentration of these three elements in the lSI measurement is 4.07E-6 Bq/cnr', while for the 2nd measurement is 7.37E-6 Bq/cnr' . Although the samples are taken in the same room, the next day measurement (2nd measurement) results in higher concentration. The concentration becomes higher in the 2nd measurement because two air suction ports in the room are closed from the day before. In the 1st measurement, these two ports are closed just before the sampling is performed.

The experiment results show that the proportion of each element to the total of these three elements seem to be constant.. The following table shows the proportion of element obtained in the 1st and 2nd measurement. . From the table it is known that the proportion of Pb-212 is 1.92 ± 0.58 %, Pb-214 is 62.09 ± 2.78% and Bi-214 is 35.99 ± 3.36%.



Element	1st, (%)	2nd(%)	~vera__&e_io/~
Pb-212	1.50	12.33	1.92±0.58
Pb-214	60.13	164.06	~2.09 ±2.78
Bi-214	38.37	133.61	135.99±3.36

The second measu ring method similar with that used in measuring beta-gross experiment is perfiormed. Figure ... shows the data obtained from the measurement. .

Solid lines in this figure are the results of theoretical calcul ation. The theoretical calculation is done based on the average count rate of Pb214 at the end of air sampling (90.26 cpm). It is also assumed that the nuclides attain equilibrium at the end of air sampling so that the initial atomic number of Bi-214 can be calculated from the following relat ionship

(No. 1.0)Pb=(NO.A.O)Si.

This relationship caJculates Ao for Bi-214 to be 77.58 cpm.

The number of daugther atoms at time t after sampling can be calculated by

$$N_{20}\, e^{-\lambda 2\, t} + N_2,$$

Where N2 is calculated by the following equation:

$$N_2 = N_{10}\frac{\lambda_1}{\lambda_2 - \lambda_1}\left(e^{-\lambda 1 t} - e^{-\lambda 2 t}\right)$$

Element	Energy, keY	counts
Pb-212	238.66	145± 11
Pb-214	351.94	lSOO±28
Bi-214	609.37	r06 ± 29

Element	Acs, Bq	C, Bq/cm'
Pb-212	3.21 ± 0.12	~.llE-08 ± 2.22E-09
Pb-214	33.51± 1.78	12.45E-06± 1.30E-07'
Bi-214	44.62 ± 3.58	1.56E-06± 1.25E-O'j

CONCLUSIONS

Experiment on measurement of radioactivity in air using gamma spectrometry has been done and the following are clarified:

I. The radioactivity concentration of Pb-212 in the gamma counting room #1 is in a range of6.lle-8 - l.72e-7, Pb-214 in a range Of 2.45e-6 - 4.72e-6, and Bi-214 in a range of 1.56e-6 - 2.48e-6 Bq/cm'.

2. The concentration calculated at the second day shows a higher value than the first day. The higher value is obtained due to the fact that two air suction ports are closed for about 24 hours before the 2nd measurement is initiated.

The ratio of each element (Pb-212, Pb-214, Bi-214) to the total of these three element seems to be constant:. Pb-212: 1.92%, Pb-214: 62.09%, Bi-214: 33.61%

REFERENCE

1. Knoll, Glen F. Radiation Detection and Measurement 2nd Edition, John Willey & Sons, New York (1989)