Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 17-18, 2018

The introduction of the methodology to calculate the air concentration in KOMAC

Yi-Sub Min [a*], Sung-Kyun Park[a], Jeong-Min Park [a]
[a]*Korea Multipurpose Accelerator Complex, Korea Atomic Energy Research Institute,*
181, Mirae-ro, Geoncheon-eup, Gyeongju-si, Gyeongsang buk-do, 780-904, Korea
[*]*Corresponding author: ysmin@kaeri.re.kr*

1. Introduction

Korea multi-purpose accelerator complex (KOMAC) is branched off from Korea atomic energy research institute (KAERI). This facility has been currently operating a 100-MeV high-power proton accelerator, low-energy ion beam accelerator, and 1.7-MV tandem accelerator to offer an optimum proton beam and various ion beam services. After high energy proton beams made from the 100MeV proton linear accelerator interact with a nucleus of the target in the target room, induced radiation should be also emitted as the secondary particles by the interaction of (p,n), (p,np), (p, 2n), (p, α), and so forth. And these particles could be activating a surrounding components as well as an airborne. The radiation workers and experiment users worked in the radiation controlled areas can be exposed to the hazards of inhalation of a radio-active material as well as the ionizing radiation generated by this proton linac. The level of the air concentration should be monitored by the radiation monitoring system (RMS). Moreover, in order to monitor the airborne radioactivity systematically in the accelerator facilities, the air contamination measurement should be carried out periodically. For the airborne contamination measurement, the air-sampler to collect the airborne radioactivity is installed near the measuring place first, shown in the left side of Fig1. The air-sampler has trapped the airborne particulates in air with 60 LPM. The total amount of radioactivity on the filter installed in the air-sampler has been measured using the low background alpha-beta counter, shown in the right side of Fug1. In this research, the equation and its uncertainty to calculate the air concentration from the radioactivity collected on the filter should be shown.

Fig. 1 The air-sampler (left) used to collect the air near the shielding door in the preparing room and the low background alpha-beta counter (right) used to measure the activities for the alpha and beta on the filter, which installed in the air-sampler.

2. The equation to calculate the air concentration

To manage the airborne radioactivity, the important value is not the total amount of radioactivity in the atmosphere, but the concentration of the radioactivity defined as the activity per unit volume [1]. The amount of the radiation dose affecting humans is time dependent and related to the airborne radioactive concentration. The longer one breathes a radioactive contamination, the larger the dose to the organ system of the body will become.

There are two parts in the equation to calculate the air concentration: In the first part, the amount of radioactivity particles is increasing constantly by the trapping of the air-sampler. We assumed that the rate of the amount of the airborne particulates per unit volume is constant in any places of the radiation controlled area and the general working area. That is, the air concentration is constant. Since the radioactive particles trapped by the air-sampler have been decayed with the passage of time, in the second part of the equation the amount of radioactivity particles has been decreased. The formula to calculate the air concentration is the given by the following:

$$\frac{dN_t}{dt} = \frac{\mathrm{C}\cdot\mathrm{F}\cdot\mathrm{t}}{E_F} - \lambda\cdot N_t \quad (1)$$

where N_t is the amount of radioactive particles at the time t, C is the air concentration with the unit Bq/m^3, F is the flow rate of the air-sampler, E_F is the collection efficiency of the filter, λ is the rate of decay constant of the unknown radioactivity measured in the airborne particles sampled. Since E_F is usually very high(99%), so that this term may be ignored and the air concentration is constant related to the time variable, the equation (1) can be transformed to the form of the equation (2).

$$\int_0^{N_0} \frac{1}{C\cdot F\cdot t-\lambda\cdot N_t} = \int_0^{t_s} dt \quad (2)$$

where N_0 is the amount radioactivity particles after finishing the trapping of the airborne particles and t_s is the time after finishing the air sampling. Since the activity is defined as the number of unstable atomic nuclei that decay per second in a given sample, the activity can be A = $\left|\frac{dN}{dt}\right|$ =$|\lambda\cdot \mathrm{N}|$. The air concentration,C is defined as the equation (3) after finishing the trapping by the air-sampler. The activity, A_0 is the radioactivity measured immediately after finishing the trapping.

$$C = \frac{\lambda \cdot N_0}{F \cdot t_s(1-e^{-\lambda \cdot t_s})} = \frac{A_0}{F \cdot t_s(1-e^{-\lambda \cdot t_s})} \quad (3)$$

In equation (3), there are two parameter measured by the low background alpha-beta counter to calculate the air concentration, C: the activity, A_0 in unit of Bq and the decay constant λ in unit of 1/hour. In order to calculate the decay constant λ, samples have measured several times over time. Fig. 2 and 3 shows the measurement result for the alpha and beta radioactivity made from the low background alpha-beta count, respectively. Their fitting results are also shown in Fig. 2 and 3.

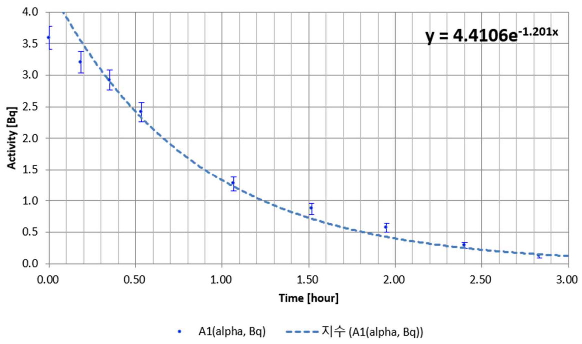

Fig. 2 The alpha activity on the filter of the air-sampler measured in the low background alpha-beta counter and its fitting result using the exponential function.

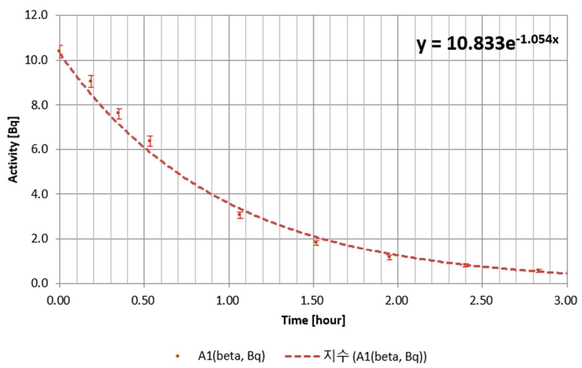

Fig. 3 The beta activity on the filter of the air-sampler measured in the low background alpha-beta counter and its fitting result using the exponential function.

The decay constant of the unknown alpha and beta particulates calculated from the fitting as shown in Fig. 2 and 3 is 1.201 and 1.054, respectively. The power series of the mathematics for $|x| < 1$ show the following relations:

$$\frac{1}{1-x} = 1 + x^2 + x^3 + \cdots \quad (4)$$

When the sampling time of the air, t_s is one hour, the part $e^{-\lambda \cdot t_s}$ of the equation (3) for the alpha and beta is 0.301 and 0.349. Thus, the part $\frac{1}{1-e^{-\lambda \cdot t_s}}$ of the equation (3) is approximately 1.419 and 1.513, respectively. The air concentration defined in the equation (3) means the activity per unit volume, however, the activity is little bigger than one measured immediately after finishing the sampling. That is, this increasing amount has corrected the effect of the decay of the radioactivity. When the alpha activity, A_0 is 3.81 Bq, the air concentration for the alpha is 1.5 Bq/m^3. By the same method for the calculation, the air concentration for the beta is 4.6 Bq/m^3 with the activity 10.94 Bq as the beta activity measured on the low background alpha-beta counter. In order to check the change of the activity in this paper, the calculated values are not compensated for the background value and the activity of the radon and its progeny.

3. The uncertainty

In order to calculate the uncertainty of the air concentration for the alpha particulates, the standard uncertainties of the variables should be considered, shown in Table I. And then, after calculating the sensitivity coefficient of the variables, the combined standard uncertainty should be calculated. When the alpha activity, A_0 is 3.81 Bq, the combined standard uncertainty is 0.15. The uncertainty at about 95 % confidence level is 0.3 Bq/m^3. By the same uncertainty calculation method for the beta particulates, the uncertainty for the beta is 0.92 Bq/m^3.

Table I: The calculation of the uncertainty for the alpha

Variable	Standard uncertainty,	Sensitivity coefficient	uncertainty contribution amount	The degree of freedom
A_0	7.9E-2	4.0E-1	3.2E-2	∞
F	3.5E+2	-4.2E-4	-1.5E-1	∞
t_0	9.6E-3	-2.3E+0	-2.2E-2	∞
Combined standard uncertainty			1.5E-1	∞

4. Conclusions

In this paper, we have introduced the method to calculate the activity on the sampling filter. First of all, the decay constants of the unknown alpha and beta particulates are calculated from measured data several times over time. The contamination concentration for the alpha and beta from the equation (3) should be calculated using the decay constant λ and the activity, A_0 measured immediately after finishing the sampling. Their uncertainties for the alpha and beta should be also calculated from the combined standard uncertainty.

REFERENCES

[1] Mark L. Maiello, Mark D. Hoover, Radioactive Air Sampling Methods, CRC Press (2010)
[2] Sung-Kyun Park, Yi-Sub Min, and Jeong-Min Park, The introduction of the periodic measurement activity to monitor the air contamination in KOMAC, KNS, (2018)