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MDA Changes due to Prolonged Measurement Time for an HPGe System

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1. Introduction

In a gamma spectrometry, we usually decide the existence of a radionuclide and report its activity when the net counts of the associated peak in the region of interest (R.O.I) is bigger than the detection limit considering Poisson statistical fluctuations [1]. The activity level associated with the detection limit is the Minimum Detectable Activity (MDA). The MDA plays an important role in low level environmental activity measurements because it defines the smallest activity of radionuclide which can be detected in a sample with a detecting system, e.g. an HPGe system [2,3].

In present, three MDA calculation methods are widely used: (1) Curries Method, (2) KTA method of the Nuclear Safety Standards Commission of Germany and (3) the recommended method from International Organization of Standardization ISO11929 [4]. The main goals of this study are to analyze the differences between Currie and KTA methods and to identify significant trend of MDA changes when the measurement time is prolonged. MDA study samples will include low-level soil in Korea and target peaks and isotopes in gamma spectrometry are ^{228}Ac (755 keV) and ^{137}Cs (662 keV). We select measurement time to be a controlling parameter from zero to 48 hours, and for every increment of one hour the HPGe gamma spectrum is saved.

2. Methods and Results

The parameters were defined similarly next that L_D is the detection limit, MDA is the minimum detectable activity and R.O.I is Region of Interest. Generally, a confined peak case of MDA calculating process distinguished from none peak case.

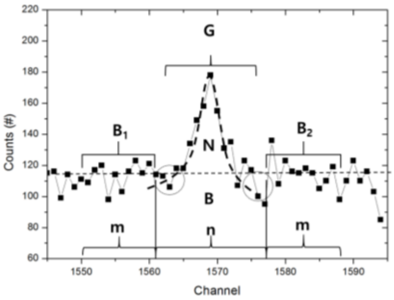


Figure 1. Representation of peak net counts(N), background under the peak(B) and neighboring background counts (B_1 and B_2).

The estimating background counts of R.O.I is non-different between Currie method and KTA method in general. The background counts are calculated by the least squares approximation such as the linear equation or the step function. the program uses the equation (1) to estimate a Compton continuum of R.O.I.

$$B = (C_B / 2m) \cdot (B_1+B_2) \text{ --- Eq. (1)}$$

Here, B is the back-ground counts. B_1 is the left side back-ground counts. B_2 is the right side back-ground counts. C_B is the channel number. m is continuum channel. And the net counts were estimated with that the background counts subtract from the gross counts are the net counts.

2.1 Currie Method

MDA calculated by Currie Method of Genie 2000 and Aptec program have both a non-peak case and a peaked case. The non-peak case is undetected by a peak searching algorithm; always the program uses a resolution (FWHM) from a correction data to estimate R.O.I. And L_D is estimated by the equitation (2).

$$L_D = k^2 + 2k \text{ sqrt}(2B) \text{ --- Eq. (2)}$$

Another case on Genie 2000 is detected by it. R.O.I of the case is calculated with FWHM out of the spectrum fitting results. And L_D is calculated by the equation (3).

$$L_D = k^2 + 2k \text{ sqrt}(B(1+C\_B/2m) \text{ --- Eq. (3)}$$

Here, k is statistic confidence level.

2.2 KTA Method

MDA of KTA method was depended by L_D of Passion statistic distribution and other parameters. The detection limit is calculating from equation 3 for both cases of a peaked case and a non-peaked case. The back-ground counts are calculated to use B_1 and B_2. And the uncertainly of B base the error of B_1 and B_2[6]. MDA was calculated that L_D was divided by the parameters such as the measure time, efficiency, gamma release rate and other effects of the detector. In the calculate, MDA of both a peaked case and a non-peaked case were equally computed by the algorism. It uses the equation 4.

$$MDA = L_D / (\text{Volume} * \text{Eff} * T) \text{ --- Eq.(4)}$$

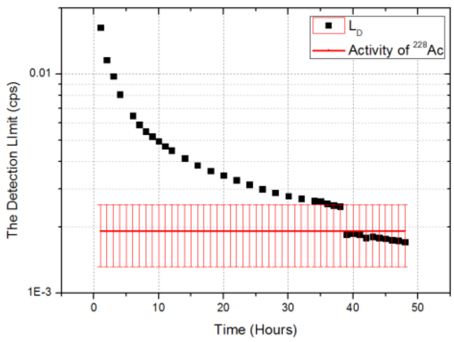
The equation 4 is to calculate MDA in general. Eff is the absolute measure efficiency. T is the measure time; it is the gamma fraction. The equation is generally used in this field for MDA calculation of gamma spectrometry analysis. But MDA calculate method of ISO-11929 more have the correction factors such as the uncertainly of T and Eff.

2.3 HPGe system

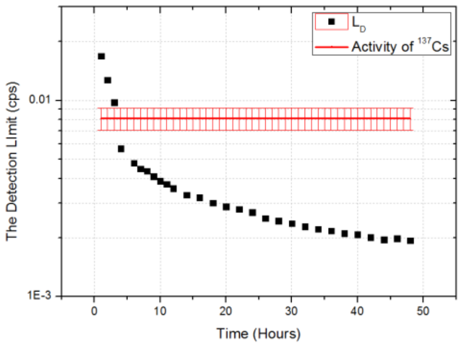
For this study, we taken some soil of 3 kg. After sampling, we had started the pretreatment. And we made the final sample of the Marinelli beaker of 1 L (1.25 kg) in sequence. The detector that have efficiency of 30% and p-type semiconductor produced by ORTEC firm. The data collection program is MAESTRO coded by ORTEC. The analysis parameters were used such as the estimating equation of R.O.I back ground is the linear fitting. And R.O.I each end channels for counting channel is 5 channels. The confidence level factor of MDA is 1.645 (95% confidence level) [5,6].

2.4 Results

L_D of 755 keV of ^{228}Ac dropped at 39 hours after measure start in the soil sample. And L_D of ^{137}Cs dropped at 4 hours.



(a)



(b)

Fig. 2. (a) ^{228}Ac's L_D was dropped (the black line is L_D of 775 keV gamma-ray, the red line is the counts rate of 775 keV gamma-ray). (b) L_D of ^{137}Cs was dropped(the black line is L_D, red line is the counts rate of 662 keV).

Gamma ray MDA of 755 keV energy was dropped approximately 23 % on Currie method, ~ 38 % on KTA method by a peak determined algorithm in the case of the detection rate of ^{228}Ac is 0.0019 ± 31 % cps. 662 keV energy was dropped approximately 36 % on Currie method and 51 % on KTA method in the case of the detection rate of ^{137}Cs is 0.0081 ± 13 % cps.

3. Conclusions

Preliminary results showed that MDAs tend to decrease for prolonged measurement time, as expected. As measurement time increases, some collection of counts which wasn't identified as peaks gets to become an identified peak (^{137}Cs peak at t = 4 hours and ^{228}Ac peak at t = 39 hours) and shows a big MDA decrease.
The MDA reduction was about 23% ~ 36% for Currie method and about 38% ~ 51% for KTA method. The reduction is thought to come from the difference algorithm in the background count calculation, R.O.I estimation and its assumptions.

The future scopes of this study will include detailed MDA analysis to explain the MDA reduction, introduction of variance reduction factor or deviation from Poisson statistics for the analysis of background counts.

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