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Minimum Periodic Function Test of HPGe Detector Using ^{152}Eu Certified Reference Materials

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ABSTRAK

Tujuan dari penelitian ini adalah untuk menentukan minimal tes fungsi periodik untuk validasi pengukuran untuk sampel lingkungan. Dalam makalah ini, EU 152 digunakan sebagai sumber untuk mengukur kalibrasi energi serta efisiensi. Kualitas kontrol pada saluran monitor kalibrasi energi berubah pada energi 121,78 keV. Selain kalibrasi, pengujian juga dilakukan pada Aktivitas Deteksi Minimum pada sistem ini. Hasil pengukuran kemudian divalidasi menggunakan sampel lingkungan.

Kata Kunci : Gamma-ray spektrometri; Kalibrasi; MDA

ABSTRACT

The purpose of this research is to determine a minimum of periodic function tests for measurement validation for environmental samples. In this paper, the EU 152 is used as a source for measuring energy calibration as well as efficiency. Control quality on energy calibration monitor channel changes in energy 121.78 keV. In addition to calibration, testing Minimum Detectable Activity on this system. Results from measurements are then validated using environmental samples.

Keywords : Gamma-ray spectrometry; Calibration; MDA

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1. Introduction

Gamma ray is wave that have an energy range of more than 10^8 eV with wavelengths smaller than 10^{-11} m. Gamma ray itself can be released of energy from radioactive substances from disasters such as nuclear explosions in Fukushima [1] This disaster release radioactive nuclide that can be contamination in the air, darts and oceans. In certain activity and substances, radioactive contamination can threaten the life of organism either directly or indirectly [2].

High pure germanium (HPGe) gamma spectrometer is a detector often used to calculate radioactive release activity while identifying its radinuclides. The detector has good efficiency and resolution [3]. However, to determine the accuracy calculation and performance of this equipment, it needs a minimum test that is well validated according to national and international standards. Validation of the measuring method is based on the performance aspects that have been tested and developed in previous studies [4]. Some aspects and test that can be done to improve and to maintain the performance of HPGe gamma spectrometer include like checking on the coolant detector that can affect the detector resolution [5], energy calibration and efficiency of the system to obtain a good qualitative and quantitative analysis result [6], background calculations and a minimum detecable activity (MDA) calculation to ascertain the smallest activity that the detector can [5]. This aspect will be important because in measuring samples that have low activity is needed accuracy in radiomentric analysis. In this article, samples known to their activities will be counted and analyzed based on the routine. The information is used to ensure the accuracy of the analysis at the gamma spectrometer owned.

2. Experiment

2.1. Caracteristic Detector

Experiment conducted in Gama Radiometry Laboratory of Center for Technology of Radiation Safety and Metrology (PTKMR) BATAN. The detector used by HPGe gamma spectrometer Canberra. This gamma spectrometer system uses nitrogen cooling system, preamplifier, bias supply detector, linear amplifier, the analogue to digital converter (ADC), multichannel analyzer system with 8192 channel, data storage on the computer and shield made of copper with thickness 11.5 cm surrounded the detector. Shield is useful to withstand the gamma ray of the environment. Detector operated at high voltage of 3 kV, with relative efficiency of 30%. In addition, the detector is covered with aluminium foil to avoid contamination of samples.

2.2. Calibration Function Test

Energy and efficiency calibration in this study is based on [3] with some modifications. This calibration is using certified standard sediment with known activity of 37.520 kBq of ^{152}Eu at 1 February 2011 which was then counting for an hour. This standard which has heavy weight 1 kg using Marinelli beakers adapted to the shape of the detector. This calibration is done every time after gas filling nitrogen using the application. its value is automatically calculated by GENIE 2000. This activity is routine to avoid loss of peak stability information on the channel. Energy calibration has been done by marking all the peaks that appear and equate with the standard source ^{152}Eu. The efficiency (ε) calibration value determined by using information activity, acquisition time, abundance, intensity of energy that calculate in the following equation:

$$\varepsilon = \frac{A}{(t \cdot \Lambda \cdot i)} \qquad (1)$$

where A is an area of peak energy ^{152}Eu, time measuring is t, Λ is the absolute activity standard ^{152}Eu [Bq] at the time of counting [Bq] and *i* is intensity or abundance of the standard ^{152}Eu.

Minimum detectable activity (MDA) is one of the most frequently used for validation methods. On this research MDA calculated using sources containing ^{226}Ra, ^{232}Th and ^{40}K. The calculation of MDA is done according to the journal published by Suseno & Prihatiningsih [7]. The MDA formula used in this paper is:

$$MDA = \frac{2.71 + 4.65\sqrt{B}}{tmEY} \qquad (2)$$

where B is background count, t is measurement time, m is sample mass, E is efficiency of detector and Y is effective yield.

3. Result and Discussion

In the beginning, the energy and efficiency calibration at the system was performed at 3000 V. The conversion gain of the system is 16384 eV with lower limit detection (LLD) 3% and upper limit detection (ULD) 100%. The selected energy in this calibration includes 121.78, 224.69, 344.28, 778.9, 964.13, 1112.11 and 1408.01 keV respectively. The chosen energy has been considered because it has a better activity and peak.

Table 1 show the difference between reference energy and energy that is legible by the system. The difference between the two energy is not significant. Besides the peak produced by the standard is quite high so we can still guess the peak.

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Table 1. Peak position of energy ^{152}Eu lines of calibration sources at 25 September 2019

Radionuclide ^{152}Eu		Peak Area	Intensity (%)	Efficiency (%)	Channel.
Energy (keV)	System (keV)				
121.78	121.6	260315	28.4	1.056	507
244.69	244.8	58472	7.49	0.90	1020
344.28	344.4	179659	26.6	0.77	1435
778.9	779.1	49816	12.96	0.44	3245
964.13	964.1	50342	14.34	0.40	4015
1112.11	1112.3	43933	13.55	0.37	4632
1408.01	1407.9	57021	20.87	0.31	5863

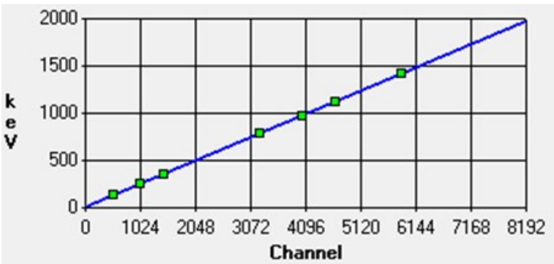

Figure 1. Curve of Energy Calibration ^{152}Eu gamma spectrometry

Taking information from the table 1, the calibration curves obtained that presented in figure 1. Despite the difference between standard and system, this difference does not have a significant impact because it is still at the desired tolerance range of 1 keV. The energy calibration curve on figure 1 also shows the linearity with the calibration energy equation as follows:

$$E= -2.\ 701.e^{-0.001}\ keV+2.405.Channel \quad (3)$$

To achieve good research results, the stability of energy calibration is always monitored periodically. Energy shifting can occur any time, so if a shift larger than 1 keV is observed will be recalibrated. Determination of this tolerance has a reason that in the research activities of energy values of the desired radionuclides are not adjacent to each other until less than 1 keV. Therefore, the determination of the value of tolerance can be slightly larger 0.5 keV than the one discovered by Xhixha et al. [8]. Figure 2 show a quality control (QC) chart for the channel shifting stability calibration in various energies ^{152}Eu.

Channel shifting stability was made from 16 November 2018. This date is a periodic function test date to monitor the performance of the performance of the detector. This date is also used as a reference to see the changes occurring on the detector. This stability was starting from 16 November 2018 to 25 September 2019 and for each measuring with 3600 s acquisition time. Fig 2 show indicates the Δ channel is the channel difference a

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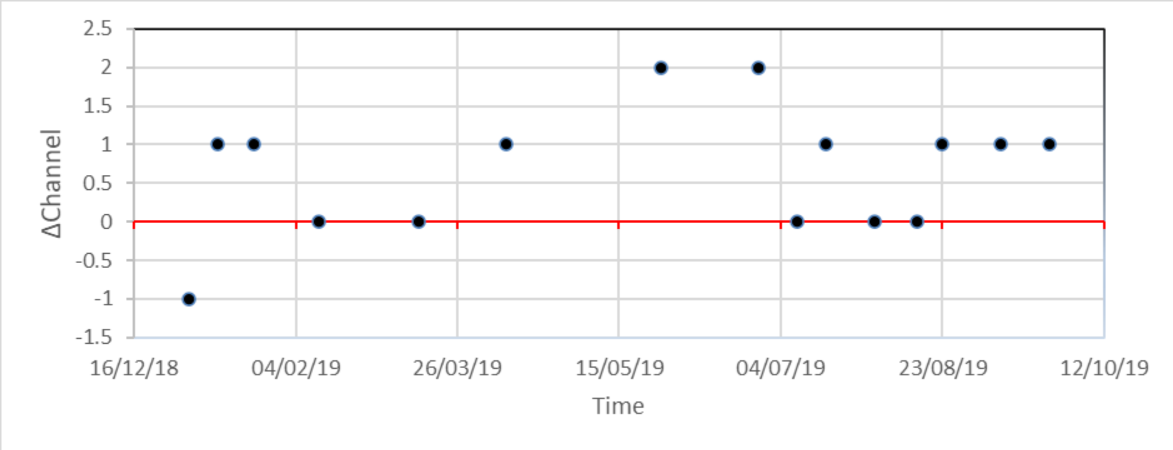

Figure 2. QC chart of channel shifting stability

from the last channel minus the channel at the beginning of the periodic function test time. Δchannel taken in this figure is a channel on the energy 121.6 keV. Reason for channel retrieval in this energy due to this energy which has abundance or the highest intensity in the ^{152}Eu. The largest channel shifts in this study that is 2 channels at or equivalent to 0,54 keV with 0.27 keV per channel. Channel shifts in this research show that the stability of the detector is still very good because this shift is still far below the tolerance of 1keV. In addition, the shift on this channel has no harmful impact in the research because radionuclides energy on the channel range is quite far apart.

In addition to energy calibration, efficiency calibration is quite important. The efficiency calibration results that have been done on this research are shown in Figure 3 using the same certified spectrometric etalon sources ^{152}Eu. The result of this calibration has a curve shape similar to [9] [10]. The efficiency calibration curve uses a dual curve with the order of the polynomial is 3. Value of efficiency obtained from the area of peak energy divided by the sample activities at the time of calibration, acquisition time and intensity of the energy ^{152}Eu. Another minimum periodic function test in addition to energy calibration and efficiency is Minimum Detectable Activity. Table 2 shows the results of MDA on radionuclide ^{226}Ra, ^{232}Th and ^{40}K. The results of this table show the MDA at acquisition time for 3 days. The longer the calculations will result in a smaller MDA. and will be very suitable for environmental samples. MDA value for this result is rated goodly enough for environmental samples that have low activity.

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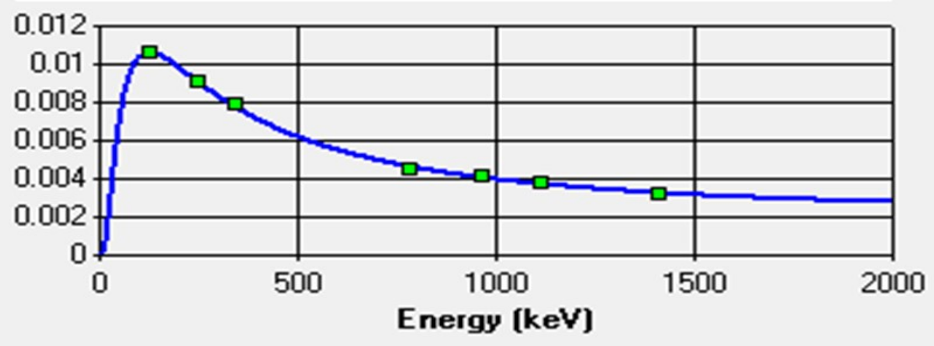

Figure 3. Efficiency curve using a source of ^{152}Eu at 29 September 2019

3.1 Experimental for Measurement of Soil Samples

Sediment samples were taken from Ambon which were then used for radiation monitoring purposes. The sample was taken using a scope on the shoreline of Ambon and then dried using an oven at 110 ^{o}C for 4 days until the sample is completely dry. Next the dried sample was crushed using a grinder then put into the mariner beaker and weighed 1 kg. And then the sample which was dried was crushed using a grinder and then put into the Marinelli beaker, weighed 1 kg and shielded. And then the sample which was dried was crushed using a grinder and then put crushed using a grinder and then put into the Marinelli beaker, weighed 1 kg and shielded. After that, the samples were stored for more than 21 days and counted using a gamma spectrometer. Sediment samples that have been stored are then counted for 3 days. Average specific activity concentrations of the samples show in table 3.

From the table which is 3 visible results of analysis using gamma spectrometer that has been well calibrated with a good qualified for environmental samples. The resulting uncertainty is also comparable with some publications that have been published. This indicates that gamma spectrometer is very feasible to calculate low-activity radionuclides.

Table 2. The Minimum Detectable Activity (MDA) of the systems

Nuklida	Energy (keV)	Area Background	Photopeak Efficiency	Emmision probability (%)	Tcount (s)	Kf 95%	MDA
^{226}Ra	351.93	1.06 x10^{3}	1.01 x10^{-2}	0.358	259200	1.645	5.71 x10^{-2}
	609.31	1.07 x10^{3}	6.70 x10^{-3}	0.448	259200	1.645	6.92 x10^{-2}
^{232}Th	911.34	2.40 x10^{2}	4.92 x10^{-3}	0.266	259200	1.645	7.51 x10^{-2}
	583.14	4.27 x10^{2}	6.94 x10^{-3}	0.845	259200	1.645	2.24 x10^{-2}
^{40}K	1460	1.66 x10^{3}	3.58 x10^{-3}	0.1067	259200	1.645	6.77 x10^{-1}

Table 3. Comparison ^{40}K activities of research results with several other journals

Sample	^{40}K (Bq/kg)	Literature
Ambon	900.69±94.45	Present Study
South west coastal region of India	283±21	Uddin, John, and Abu (2012) [2]
South Kalimantan	596.83 ± 23.23	(Prihatiningsih, Suseno, Makmur,
Shama	214.67 ± 3.30	Adukpo et al. (2015) [12]
Assin Aworoso Assin	204.48 ± 2.69	

4. Conclusion

The validation and calibration of system HPGE Ortec has been carried out with a series of measurement activities found the accuracy of the gamma analysis that is owned using the certified standard. The results of this study indicate the self-system and the validation has been done well correctly and properly for measuring samples that have low activity.

5. Acknowledgement

YP was doing the measurement and calibration, WRP was giving the concept of measurement and idea of the experiment. YP and WRP are the main contributors of this paper. Authors thanks to the PTKMR - BATAN for funding support from DIPA 2019. The authors have *no conflicts of interest* to declare.

6. Referensi

1. Suseno, H., & Wahono, I. B. (2018). Present status of ^{137}Cs in seawaters of the Lombok Strait and the Flores Sea at the Indonesia Through Flow (ITF) following the Fukushima accident. *Marine Pollution Bulletin*, *127*(December 2017): 458–462. https://doi.org/10.1016/j.marpolbul.2017.12.042
2. Uddin, M., John, P., & Abu, H. (2012). Determination of Primordial Radionuclides in Natural Samples Using HPGe Gamma-Ray Spectrometry. *APCBEE Procedia*, 1 (January): 187–192. https://doi.org/10.1016/j.apcbee.2012.03.030
3. Hossain, I., Sharip, N., & Viswanathan, K. K. (2012). Efficiency and resolution of HPGe and NaI (Tl) detectors using gamma-ray spectroscopy. *Scientific Research and Essays,* 7(1): 86-89. https://doi.org/10.5897/SRE11.1717
4. Romeo, M., Mihaela, C., & Calin, A. (2011). Assessment of calibration parameters for gamma-ray spectrometry systems. *Journal of Radioanalytical and Nuclear*

Wahana Fisika, 5(2), 2020. 83 - 90
http://ejournal.upi.edu/index.php/wafi
e-ISSN : 2594-1989 https://doi.org/10.17509/wafi.v5i2.28646

Chemistry (2550). https://doi.org/10.1007/s10967-010-0961-2

5. Gilmore, G. R. (2008). *Practical Gamma-ray Spectrometry*.
6. Gupta, A., Lenka, P., Sahoo, S. K., Kale, P. K., Ravi, P. M., & Tripathi, R. M. (2017). Improvement in minimum detectable activity for low energy gamma by optimization in counting geometry. *Radiation Protection and Environment*, 2017–2020. https://doi.org/10.4103/rpe.RPE
7. Suseno, H., & Prihatiningsih, W. R. (2014). Monitoring ^{137}Cs and ^{134}Cs at marine coasts in Indonesia between 2011 and 2013. *Marine Pollution Bulletin*, *88*(1–2): 319–324. https://doi.org/10.1016/j.marpolbul.2014.08.024
8. Xhixha, G., Alberi, M., Baldoncini, M., Bode, K., Landsberger, S., Mantovani, F., … Shala, F. (2015). Calibration of HPGe detectors using certified reference materials of natural origin. *Journal of Radioanalytical and Nuclear Chemistry*. https://doi.org/10.1007/s10967-015-4360-6
9. Daraban, L., Iancu, D., Nita, D., & Daraban, L. (2013). Efficiency Calibration in Gamma Spectrometry By Using 232 Th Series Radionuclides. *Journ. Phys*, *58*: 1–9.
10. Calin, M. R., Calin, A. M., Done, L., Druker, A. E., & Calin, A. C. (2010). Assessment of calibration parameters for gamma-ray spectrometry systems Assessment of calibration parameters for gamma-ray spectrometry systems. *Journal of Radioanalytical and Nuclear Chemistry*. https://doi.org/10.1007/s10967-010-0961-2
11. Prihatiningsih, W. R., Suseno, H., Makmur, M., & Yahya, M. N. (2020). Effect of regional oceanographic processes to the distribution of radionuclides in the coasts of Kalimantan. *IOP Conference Series: Earth and Environmental Science*, *429*. https://doi.org/10.1088/1755-1315/429/1/012014
12. Adukpo, O. K., Faanu, A., Tettey-larbi, L., Regulatory, N., & Emi-reynolds, G. (2015). Distribution and assessment of radionuclides in sediments, soil and water from the lower basin of river Pra in the Central and Western Regions of Ghana. *Journal of Radioanalytical and Nuclear Chemistry*. https://doi.org/10.1007/s10967-014-3637-5