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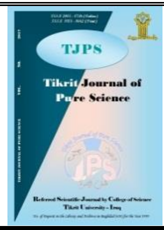

COMPARISON BTWEEN THE RELATIONS OF HpGe DETECTOR EFFICIENCY CURVE AND BACKGROUND "SPECTRUM SHAPE"

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ABSTRACT

The full energy peak efficiency (ε) relation of HpGe detector is determined and compared with the "spectrum shape" relation of natural background (BG) for the (121.8-1408) keV energy range. A one liter Marinelli beaker soil standard containing the Eu-152 material is used in calibration and measurement. A MATLAB fitting program were used obtain the efficiency relation from the experimental values, and to obtain the BG "spectrum shape" relation from the count rates at the corresponding energy values used. The ε / BG factor values were 1.154 at the 121.8keV and increase with energy till reaching a maximum value of 4.358 at about 778keV energy and then decrease. These values may be used to extract efficiency from the BG values at the specified measurement conditions. The obtained results may participate in extending our understanding of the standardization concept in radiation measurements.

1- Introduction

In gamma – ray spectrometry and in making the quantitative analysis of samples from the data of spectra registered by germanium or scintillation detectors, it is needed to know the detector efficiency since this is related to the emission rate of radionuclides. The detector efficiency may be calculated or measured, and in literature there exist a lot of papers covering this subject [1, 2].

According to the geometry of measurement system, the standard or calibrated source used should follow that geometry (point or extended source). Moreover, the standard activity should match that of the measured sample or unknown i.e. the count rate has to be of comparative value.

For investigations that involve natural radioactivity measurements, researchers are accustomed to make efficiency calibration by using calibrated Marinelli beaker standards with known activity and radionuclides information. The efficiency relation is then used in obtaining activity or concentration of radionuclides found in the samples [3].

Efficiency of germanium detectors may be estimated from published measurements or calculations for detectors of similar size but with lower accuracy results. Dimensions of detectors are not standardized to any degree, and it is very difficult to precisely determine their active volume. For such reasons and others researchers act to obtain their own efficiency calibration relation.

Sometimes there may be a difficulty in obtaining or offering a standard to make the calibration and measurement. Possible alternative candidates should follow the general requirements of count rate, material type, homogeneity besides the availability and ease in making the measurements · In the present work we investigate the laboratory background as it may meet, even partially, some of these requirements, through comparing between the standard efficiency relation and the" shape relation" of background for the same specified energy range.

2-Theoretical

The detector efficiency is a ratio of the number of particles recorded per unit time to the number of particles impinging upon the detector in that unit time. This depends mainly upon density and size of the detector material, type and energy of radiation, and system electronics [1]. In literature there exist a lot of papers concerning the efficiency of gamma detectors. The full energy peak efficiency ε of Ge (Li) detectors very nearly obeys a power law in its dependence on energy E for 100keV- 3 MeV [4].

$\varepsilon = E^{-1.4}$ … (1)

At high energies small but definite variations occur. The efficiency can then be approximated by [5].

$\ln \varepsilon = B (\ln E) + C (\ln E)^2$ …. (2)

where B and C are constants. Freeman et.al. [6] discussed a method for obtaining empirically the relative efficiency **ε** over gamma -ray range (500-1500keV). This is given by the semi-empirical formula

$\varepsilon = C [\tau + \sigma A \exp(-BE)]$ … (3)

where τ and σ are the photoelectric and Compton absorption cross sections respectively, A, B and C are constants.

A four-parameter function was proposed by East [7] for a 50 cm^3 coaxial detector in the energy range 511-1333keV.

An 8-parameter function first suggested by McNelles and Campbell [8] is given by:

$\varepsilon = (a1/E)^{a2} + a3 \exp(-a4\ E) + a5 \exp(-a6\ E) + a7 \exp(-a8\ E)$… (4)

This equation was tested for various coaxial detectors over 160-2598keV energy range and fits experimental data with no more than 1-2 percent.

For environmental radioactivity measurements using beaker sources [3] also the efficiency relations of HpGe detector used with standards were of exponential behavior and with several coefficients that differ according to the standard type. For one-liter soil beaker standard containing Eu-152 the efficiency relation found were [9]:

$\varepsilon = Y0 + A1 \exp(-Z1\ E) + A2 \exp(-Z2\ E)$ … (5)

where Y0, A1, Z1, A2, and Z2 are coefficients.

3- Experimental

The measurements were carried out using the gamma spectrometry system at physics department - college of education for pure science- university of Baghdad. A HpGe detector with 20% relative efficiency and 3keV energy resolution is used. The detector is connected to a personal computer MCA card (ICS – PCI) – SPECTECH company, that controls the accumulation and makes the data analysis. A one-liter beaker standard source is used in the measurements. This standard contains the Eu-152 radioactive material mixed with soil to give an overall activity of 1000 Bq that suits the low-level counting measurement of natural radio activity. Energy calibration is performed with using this standard. The spectrum of the standard is accumulated for 3600 sec and is shown in Fig. (1) ·The laboratory background was also measured and its spectrum is shown in Fig. (2).

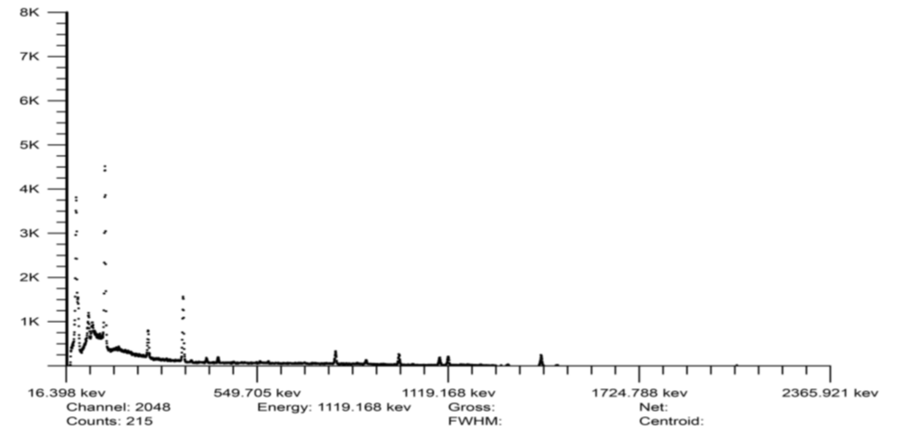

Fig. 1: Spectrum of the one-liter Marinelli beaker soil standard measured by using HpGe detector.

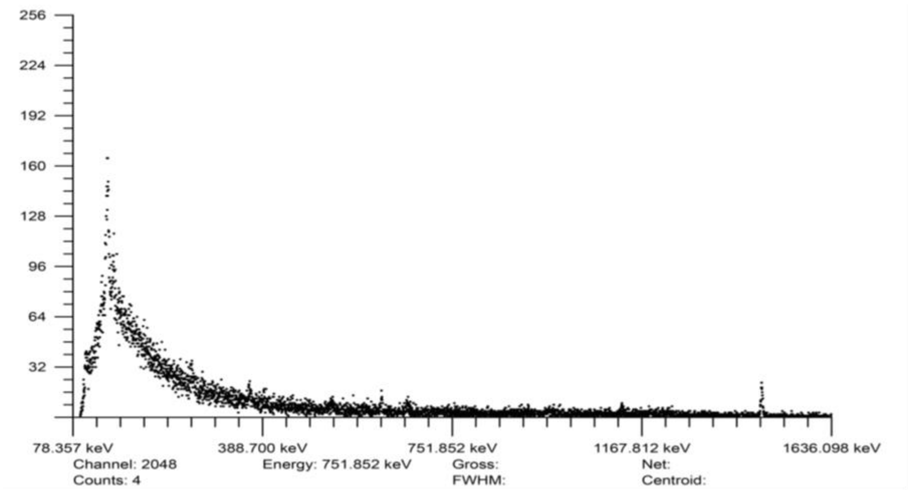

Fig. 2: Laboratory background spectrum measured by using HpGe detector.

4- Results and Discussion

4-1 -Efficiency Calculation

The full energy peak efficiency ε of HpGe detector with using Eu-152 soil standard is calculated by using the general formula:

$$\varepsilon = \frac{NPA/t}{A.I_\gamma} \quad \ldots\ldots (6)$$

where ε is detector efficiency, NPA net peak area, t counting time, A source activity and I_γ is the percentage per disintegration of the emitted γ – energy. Table (1) shows the results of efficiency calculation. However, and due to the lack in energy values below 121.8keV, the fitting process revealed only the decreasing part of the efficiency curve.

Table 1: Energies and efficiency values obtained with Eu-152 soil standard

E(keV)	121.8	244.7	344.3	411.1	443.3	778.8	867.4	964	1112	1408
ε	0.03123	0.01571	0.01207	0.00941	0.0769	0.00462	0.00216	0.00314	0.00243	0.00199

The fitting curve by using MATLAB program is shown in Fig. (3) and its equation is given as:

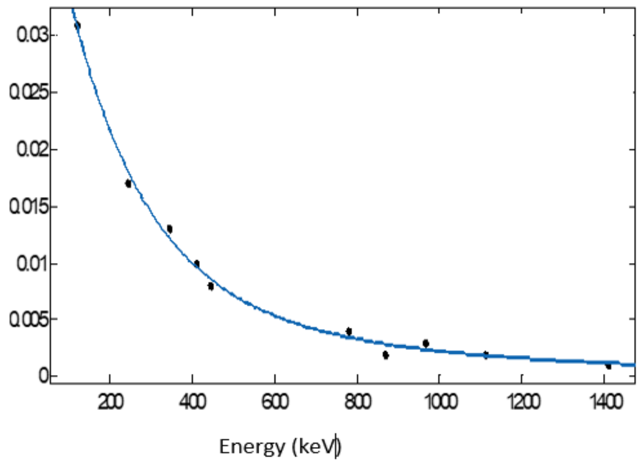

Fig. (3): Efficiency data of Table (1) fitted by MATLAB program

$$\varepsilon = a * \exp(b*E) + c * \exp(d*E) \quad \ldots. (7)$$

where E is gamma –ray energy and a, b, c and d are coefficients.

4-2 Background profile

As shown in Fig. (2) of the background (BG) spectrum, we determined the corresponding locations of Eu-152 energies on this spectrum. Table (2) shows the energies (same for Eu-152) with the counting rate at each.

Table 2: BG count data at Eu-152 energies.

E (keV)	121.8	244.7	344.3	411.1	443.3	778.8	867.4	964	1112	1408
Count (47min)	76.3	18.6	9	7.3	7	3	2.6	3	1.6	1
Count /s. unit energy	0.02705	0.00659	0.00319	0.00258	0.00248	0.00106	0.00092	0.00106	0.00056	0.00035

Using the same MATLAB fitting program, we estimated the BG "spectrum shape" relation. The fitting curve is shown in Fig. (4). Again, this covers the range (121.8-1408keV). The fitting seems very good. However, obtaining good quality data requires a fairly long measuring time. Also, spectrum smoothing may improve the results. The fitting equation is given as

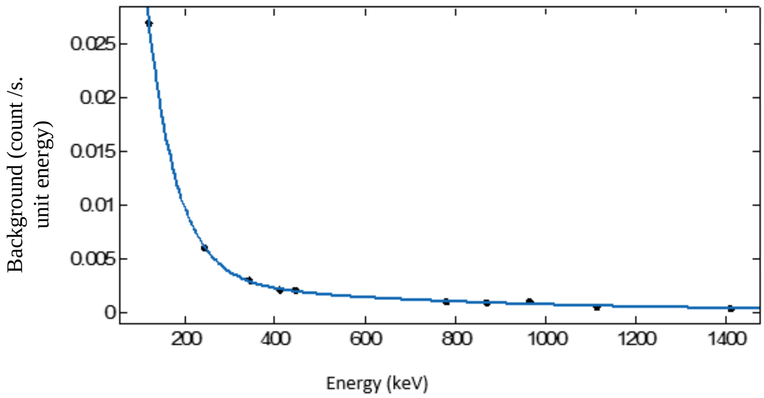

Fig. (4): Background data of Table (2) fitted by using MATLAB program.

BG (count/s. unit energy) = a * exp (b * E) + c * exp (d * E) ….(8)

where E is the gamma –ray energy and a, b, c and d are coefficients different from those in efficiency relation.

4-3- Comparison:

Before making the comparison between efficiency equation and BG "spectrum shape" relation it may be important to mention that the use of another different isotope standard may give different results. Also, the BG itself may differ in the different locations. Returning to the present results, the efficiency values are generally higher than the BG values for the corresponding energies. Table (3) shows the ε / BG factors that increase till about 778kev energy and then decrease. To ease the comparison, we found it convenient to make the y-axis of both the efficiency and BG "normalized" to a common value with same scale. We divided efficiency value at l21.8keV by the BG value at the same energy, and this gave the factor 1.154. Then all the remaining energies were multiplied by this factor as presented in Table (3). These new BG values were then fitted by using MATLAB program, and the result is shown in Fig. (5), which allows making better comparison. The new BG relation is similar to eq. (8) except coefficients values.

In cases of the unavailability of the standard or its efficiency relation, the ε/ BG factors may be multiplied by the BG measured values to extract the efficiency. It should be kept in mind that the standard efficiency relation is obtained at certain activity and the obtained results of the unknown samples will depend on it accordingly. Moreover, the results are based on an unchanged BG rate with respect to energy.

The comparison of results obtained in the present work is of numerical nature and results are thought as preliminary and the subject needs to be more investigated in different locations with using different systems. Long measuring time runs and use of data treatment techniques like spectrum smoothing are also required.

Table 3: Efficiency, BG and BG multiplied by 1.15452 data with the ε / BG factor at the Eu-152 energies.

Energy (keV)	BG (counts/s.unit energy)	ε	ε / BG	BG * 1.15452
121.8	0.02705	0.03123	1.15452	0.03122
244.69	0.00659	0.01571	2.38391	0.00760
344.27	0.00319	0.01207	3.78369	0.00368
411.11	0.00258	0.00941	3.64728	0.00297
443.97	0.00248	0.0769	3.10080	0.00286
778.89	0.00106	0.00462	4.35849	0.00122
867.38	0.00092	0.00216	2.34782	0.00106
964.05	0.00106	0.00314	2.96226	0.00122
1112.05	0.00056	0.00243	4.33928	0.00064
1408.03	0.00035	0.00199	5.68571	0.00040

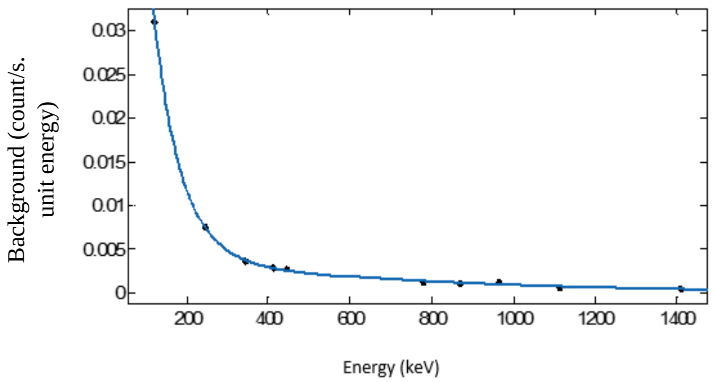

Fig. (5): Background data of Table (3) multiplied by 1.15452 and fitted by using MATLAB program.

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مقارنة بين علاقتي منحنى كفاءة كاشف HpGe و"شكل طيف" الخلفية الأشعاعية

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الملخص

حددت علاقة الكفاءة عند قمة الطاقة الكاملة لكاشف الجرمانيوم عالي النقاوة وقورنت مع علاقة "شكل طيف" الخلفية الأشعاعية (BG) لمدى الطاقة (121.8- 1408) keV. استخدم وعاء مارينيلي بحجم لتر واحد من قياسي التربة المحتوية على مادة Eu-152 لأجراء المعايرة والقياس. استخدم برنامج ملائمة MATLAB للحصول على علاقة الكفاءة من القيم العملية، والحصول على علاقة "شكل طيف" الخلفية BG من معدلات العد عند قيم الطاقات المقابلة المستخدمة. ان قيم العامل BG / ε كانت 1.154 عند الطاقة 121.8keV وتزداد مع الطاقة لتصل قيمة قصوى مقدارها 4.358 عند قرب الطاقة 778keV ثم تبدأ بالأنخفاض. ان هذه القيم ربما يمكن استخدامها لأستخراج الكفاءة من قيم الخلفية الأشعاعية عند ظروف القياس المعينة. النتائج التي تم الحصول عليها يمكن ان تساهم في توسيع معرفتنا لمفهوم التقييس في القياسات الأشعاعية.