doi.org/10.52866/esj.2021.01.18.04

COMPARISON OF NaI(TI) DETECTOR EFFICIENCY RELATION WITH THE LABORATORY BACKGROUND "SPECTRUM SHAPE" RELATION

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Abstract:

A comparison is made between the full energy peak efficiency ε relation of the 3"x 3" NaI(TI) detector and the laboratory background (BG) "spectrum shape» relation for the energy range (121.8-964.05) keV. A Eu-152 point source with about one µCi activity were used in calibration and measurement. The efficiency relation were obtained by fitting the experimental values with using a MATLAB program that was also used to obtain the BG "spectrum shape" relation from the count rates at the corresponding energy values used in efficiency calculation. The ε / BG factor values obtained were 0.0578, 0.1114, 0.1525, 0.2166 and 0.2555 at 121.8, 244.69, 344.27 778.89 and 964.05keV respectively. These values may be used to extract efficiency from the BG values at the specified measurement conditions.

Key words: NaI(TI) detector, efficiency, background "spectrum shape".

مقارنة علاقة كفاءة كاشف NaI (TI) مع علاقة "شكل طيف" الخلفية الأشعاعية للمختبر

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الخلاصة:

أجريت مقارنة بين علاقة الكفاءة عند قمة الطاقة الكاملة للكاشف NaI (TI) 3" x3" وعلاقة " شكل طيف " الخلفية الأشعاعية للمختبر لمدى الطاقة (121.8 – 964.05) keV . استخدم مصدر Eu-152 النقطي بفعالية بحدود 1 µCi في اجراء المعايرة والقياس. ان علاقة الكفاءة تم الحصول عليها بملائمة القيم العملية باستخدام برنامج MATLAB الذي استخدم ايضا للحصول على علاقة "شكل طيف" الخلفية الأشعاعية من معدلات العد عند قيم الطاقات المقابلة المستخدمة في حساب الكفاءة. ان قيم العامل BG / ε التي تم الحصول عليها كانت 0.0578 ، 0.1114 ، 0.1525 ، 0.2166 ، و 0.2555 عند الطاقات 121.8 ، 244.69 ، 344.27 ، 778.89و 964.05 keV على التوالي . ان هذه القيم يمكن استخدامها لأستخراج الكفاءة من قيم BG عند ظروف القياس المعينة.

كلمات مفتاحية: كاشف NaI (Tl) ، الكفاءة ، " شكل طيف " الخلفية الأشعاعية.

1. Introduction:

In nuclear spectroscopy, the detector efficiency is regarded as a main important parameter since it is strongly related to the emission rate of radionuclides. The detector efficiency may be determined by calculation or measurement. For gamma -ray measurements there are a lot of papers concerning this subject that are referred to in many reference books [1,2].

In natural radioactivity measurements, researchers are accustomed to make efficiency calibration 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 using same geometry[3]. Both the standard and sample should be of same size and shape. Other requirements also include the material type, homogenity, weight and count rate that should be specified as near as possible between the standard and sample.

For the type of measurements that involve using point sources, also nearly the same requirements mentioned above between the standard and unknown sources need to be followed.

A question may arise when the standard itself is not available or there is a difficulty in obtaining it, what would be the alternative that should also follow the general requirements above ?. In a recent investigation [4] the authors compared the efficiency relation of a HpGe detector obtained by using a one liter soil beaker standard with the background " spectrum shape" that may meet (even partially) some of the requirements. Following this, the present work investigates the relation between efficiency curve of NaI(Tl) detector measured by point source and background "spectrum shape".

2. Theoretical part:

In nuclear spectrometry the detector efficiency is a quantity that gives the fraction of particles being detected. It is a ratio between the number of particles recorded per unit time to the number of particles incident upon the detector per that unit time. The density and size of detector material, type and energy of radiation and system electronics are the main factors upon which the detector efficiency depends [1].

Detector efficiency can be determined either by experiment or by calculation. Many methods have been used for the measurement of detector efficiency [5-7]. But the simplest and probably the most accurate is the method of using a calibrated source. For a monenergistic point isotopic source emitting S particles per second and when the true net counting rate is r counts/second, the solid angle is Ω , then the detector efficiency ε is given by:

$$\varepsilon = r / \Omega \ F S \qquad (1)$$

where F is a combination of all the correction factors needed to be applied to the results.

Accurate absolute measurements relay on measured rather than calculated efficiencies. The basic principles of calculating the NaI(Tl) detector efficiency for parallel gamma -ray beam and point isotropic photon source are presented in ref.[1].

Another way of calculating efficiency is by determining the energy deposited in the detector as a result of all the interactions of the incident particle.

The Monte Carlo method which may be ideal for such calculations was used for that purpose by some investigators [8]. For gamma-ray detectors like HpGe and NaI(TI) Eq.(1) is written in the form:

$$\varepsilon = (NPA / t) / A.\, I_\gamma \qquad (2)$$

Where NPA is the net peak area, t is the counting time, A source activity and I_γ is percentage per disintegration of the emitted γ-ray.

3. Experimental part:

The measurements were carried out using the gamma-ray spectroscopy system at physics department/college of science, university of Al- Nahrain. The system consists of a 3"x3" NaI(TI) detector connected to a DSA1000 integrated data acquisition system (CANBERRA model), Fig. (1). Eu-152 standard point source with about one µCi activity was used for energy and efficiency calibration of the system. For efficiency measurement the spectrum of Eu-152 source was accumulated for 3600 sec. The background BG spectrum was also measured for 1000 sec. The spectra of Eu-152 source and BG are shown in Figs. (2) and (3) respectively. The spectra accumulation and data analysis were carried out using the built in Genie-2000 analysis program.

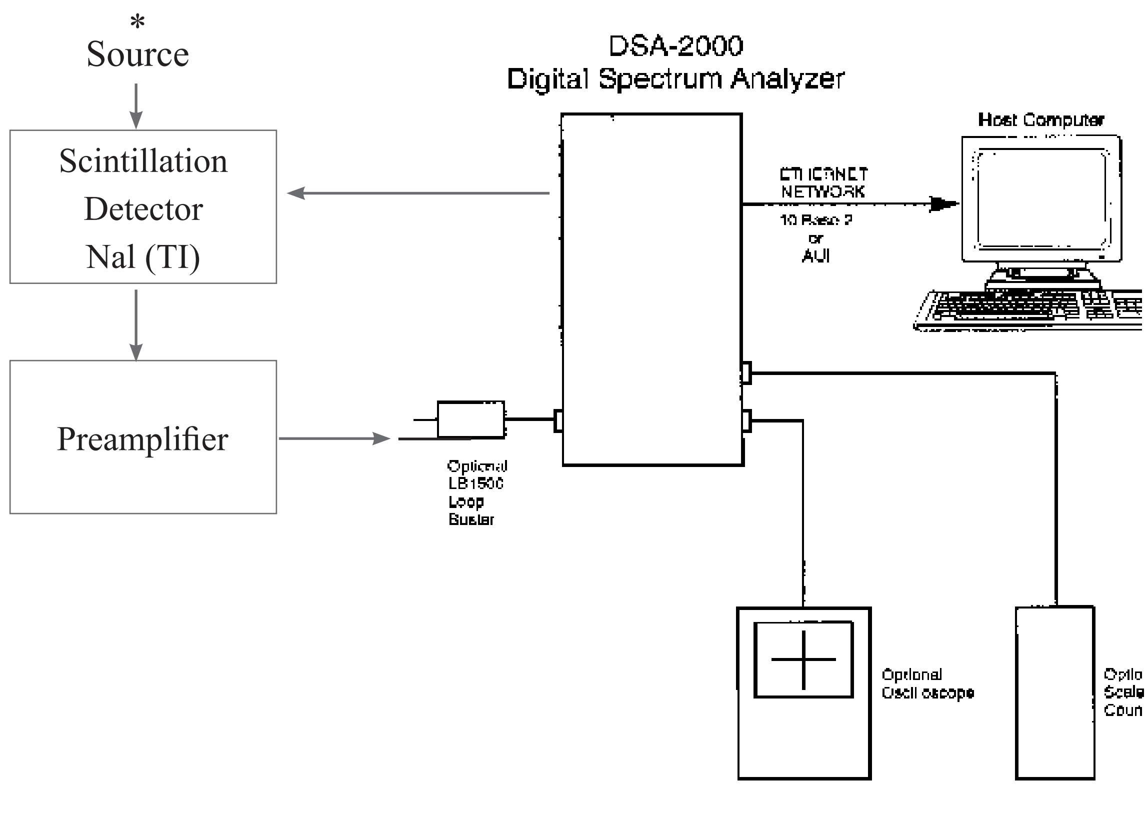

Fig. (1): The NaI(TI) detector measurement system.

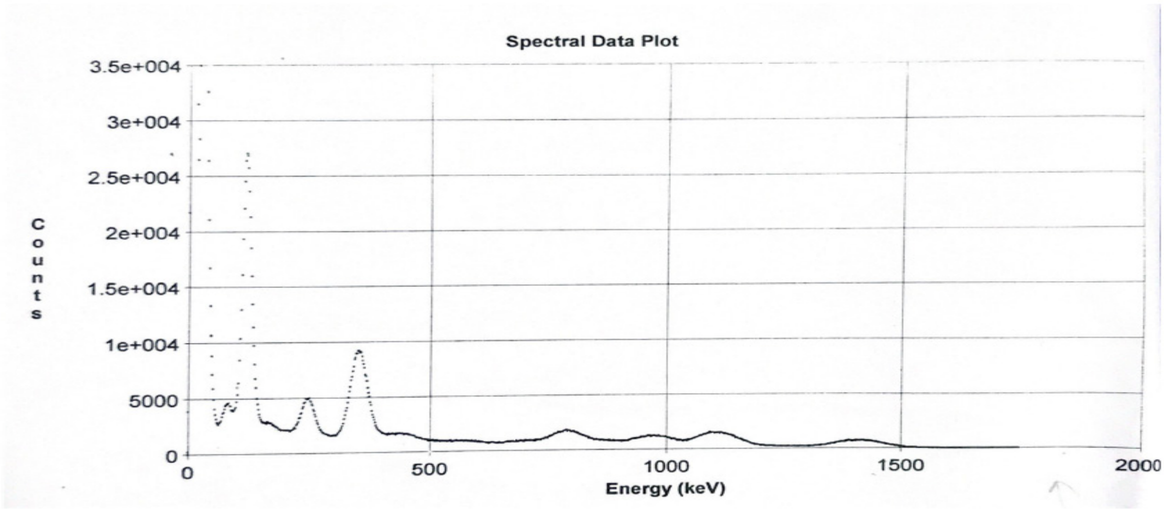

Fig. (2): Eu-152 source spectrum measured by NaI(Tl) detector.

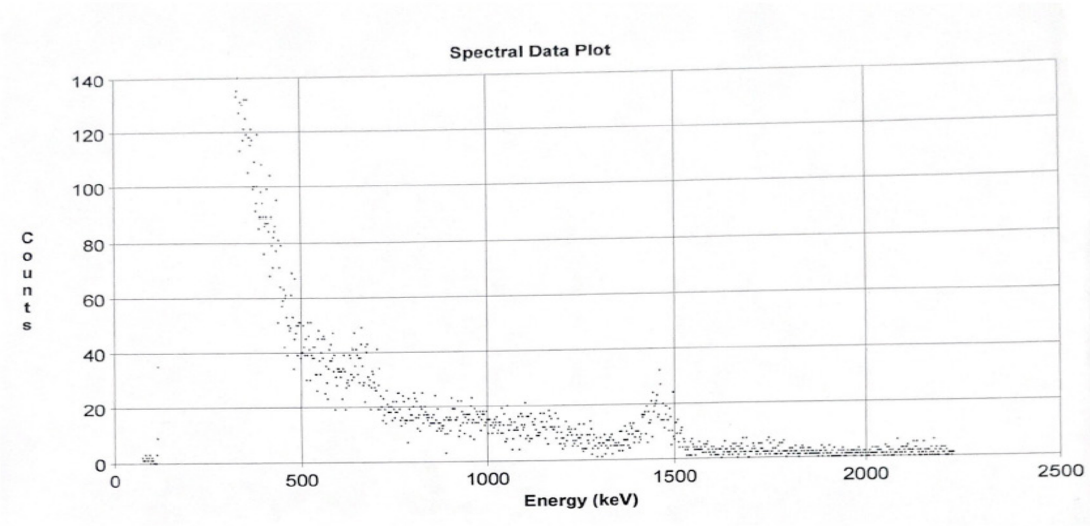

Fig. (3): Laboratory background measured by NaI(Tl) detector.

4. Results and Discussion:

The information obtained from the Eu-152 source spectrum by using the Genie-2000 program include gamma energy E_γ (keV), channel number, gross peak area GA, net peak area NPA and I_γ for Eu-152 and are presented in Table (1). Also included in Table (1) the BG (count/sec. unit energy) values at the corresponding Eu-152 energies. The full energy peak efficiency ε is calculated using eq. (2) and its values are also tabulated. It should be noted that some of the information data presented in Table (1) were excluded or even not mentioned due to the poor energy resolution and peaks interferences. The efficiency value at 1408keV were also excluded because of possible interfering with the 1460keV energy of K-40 besides the detector crystal itself has an inherent amount of the last isotope [1].

Table (1): Spectroscopic data of NaI(TI) detector efficiency and BG "spectrum shape" at Eu-152 source energies

Eγ(keV)	Ch.No.	GA	NPA	Iγ(%)	Efficiency	BG(count/s. unit energy)
121.8	71	389229	267166	28.37	0.0203	0.351
244.69	138	160447	64469	7.51	0.0185	0.166
344.27	194	273122	186534	26.58	0.0151	0.099
411.11	232			2.23		0.038
443.97	247			3.12		0.052
778.89	427	93010	39155	12.96	0.0065	0.030
867.38	473	32733	3563	4.16		0.017
964.05	523	67259	31350	14.62	0.0046	0.018
1112.05	596	91864	62851	13.56		0.007
1408.03	756	51066	42789	20.58		0.011

4 - 1 Efficiency calibration curve:

The efficiency data of Eu-152 source energies presented in Table (1) were used to obtain the efficiency curve by using a MATLAB program. The result is shown in Fig. (4), and the obtained fitted formula of detector efficiency were as:

$$\varepsilon = a * \exp(b * E) + c * \exp(d * E) \qquad (3)$$

where E is the gamma - ray energy and a, b, c and d are coefficients. The curve is peaked at about 135keV energy.

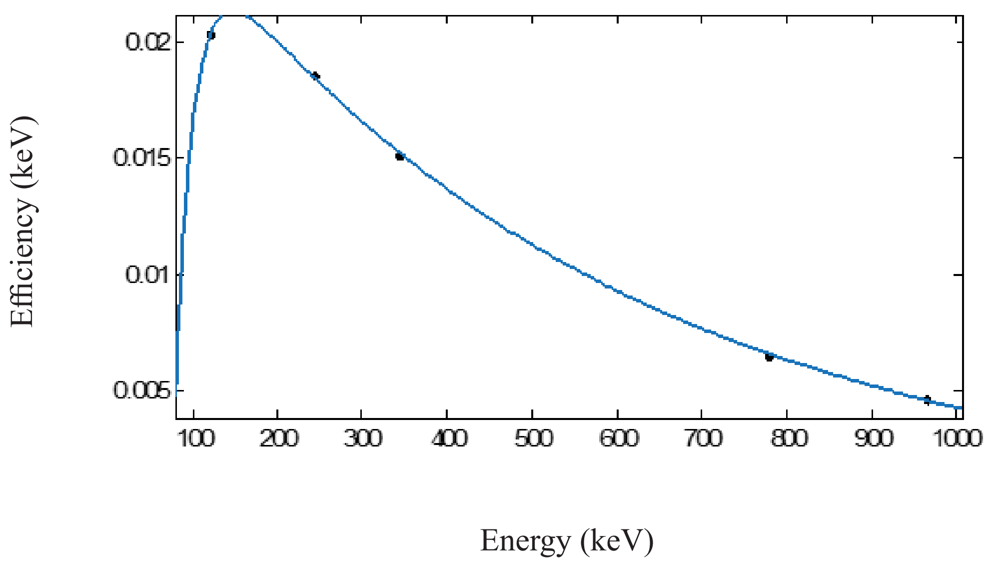

Fig. (4): Efficiency calibration curve of the NaI(TI) detector using Eu-152 source.

4 - 2: BG "spectrum shape" relation

Using the same MATLAB fitting program, the BG (count/sec. unit energy) values at the corresponding Eu -152 source energies, were used to obtain the "spectrum shape" formula of BG. Fig. (5) shows the result of BG data fitting. The obtained formula of BG "spectrum shape" relation was:

BG (count/sec. unit energy) =

$$a * \exp(b * E) + c * \exp(d * E) \quad (4)$$

Again E is the gamma-ray energy and a, b, c and d are coefficients that differ from those of efficiency relation in values and in sign for some of them.

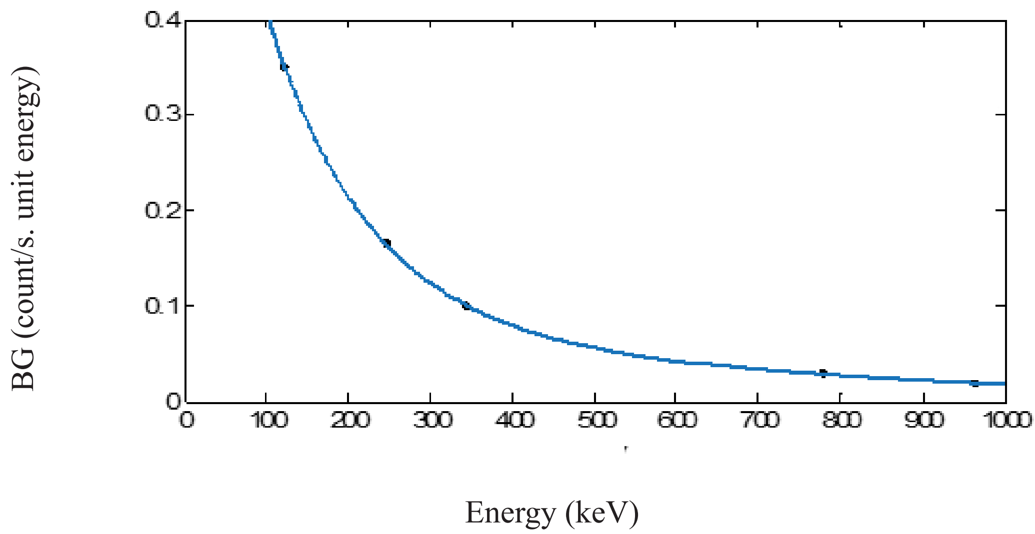

Fig. (5): BG data of Table (1) fitted by using MATLAB program.

4 - 3 : Comparison:

It may be important to mention firstly that in case of using another different standard isotope the results may be different, and the BG itself may also differ in the different 1ocations even they are near to each other. As observed in Table (1) the BG values are generally higher than the efficiency values for the corresponding energies. To allow making better comparison between the efficiency and BG"spectrum shape" relations, the y-axis of the both two previous plots was unified to a common one value at the 121.8keV energy, by dividing the BG values by the efficiency value that gave the factor 17.29. All the remaining efficiency values at the remaining energies were multiplied by this factor. The "new" efficiency values were then fitted by using the MATLAB program and gave the curve shown in Fig. (6).The new efficiency relation is similar to eq. (3) except the coefficients values.

The ε / BG factor values were 0.0578, 0.1114, 0.1525, 0.2166 and 0.2555 at the 121.8, 244. , 344. , 778 and 964keV respectively. In case of unavailability of the standard source or the efficiency relation, the ε / BG factors may be multiplied by the BG measured values to obtain the efficiency. In this case the obtained results for the unknown measured samples rely on the activity of the actual source used before. In addition to this all calculations should be according to an unchanged BG rate with respect to energy.

As mentioned previously [4], this comparison is of numerical nature and the subject needs more investigations at different locations as well as by using different systems. Data treatment techniques like spectrum smoothing with increasing BG measurement time are also required. Concluding, the results presented here are still thought as preliminary.

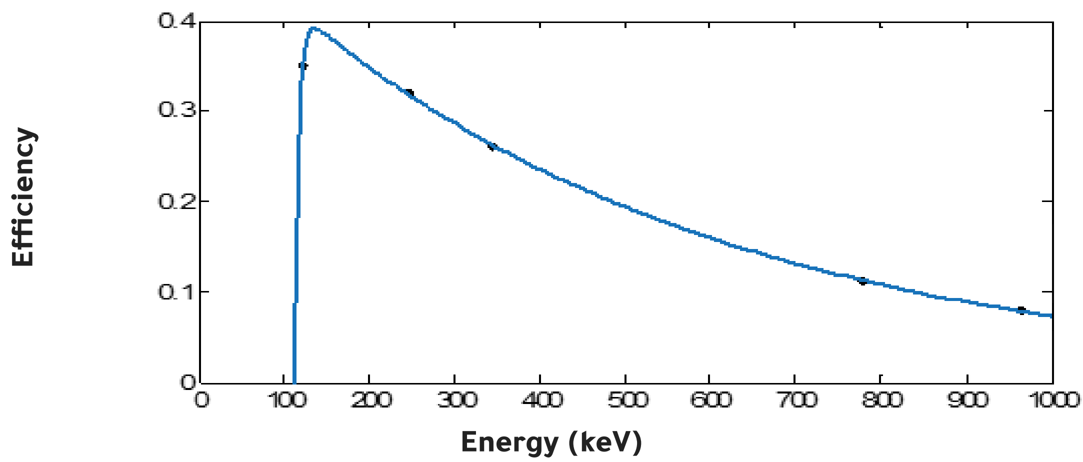

Fig. (6): Efficiency data of Table (1) multiplied by 17.29 factor and fitted by the MATLAB program.

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