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RESEARCH ARTICLE

A Comparison of LabSOCS and Source-Based Full Energy Efficiency Generation in Measurements.

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Abstract

Not all gamma rays emitted by the source that pass through the detector will produce a count in the system.The probability that an emitted gamma ray will interact with the detector and produce a count is the efficiency of the detector.Efficiency is measured by comparing a spectrum from a source of known activity to the count rates in each peak to the count rates expected from the known intensities of each gamma ray and is an important factor in measurement of activity concentration in variety of sample types. The energy of the gamma rays being detected is an important factor in the efficiency of the detector. An efficiency curve can be obtained by plotting the efficiency at various energies. This curve can then be used to determine the efficiency of the detector at energies different from those used to obtain the curve. A comparison of two gamma-ray efficiency determination methods; Canberra's LabSOCS and the source-based efficiency calibrations usingmarinelli beaker geometry were measured and the results revealed +96% confidence levels for each gamma peak lines. This means that the Canberra's LabSOCS will be used for efficiency curve generation and no more dependence on standard sources in activity concentration measurements for variety of sample matrices.

Introduction:-

Although high purity germanium detectors (HPGe) detectors come in many different designs and sizes, the most common type of detector is the coaxial detector which in centre for applied science and technology (CARST) is useful for measurement of gamma-rays with energies over the range from about 31.00keV to 2.50 MeV. Laboratories which are directly involved in the measurement and certification of the radioactive content of various samples collected from the environment and the food chain, or industrial products should development analysis procedures to qualitatively or quantitatively evaluate the radionuclides concentration involved [1]. This involves set-up for calibrations (energy and efficiency) developmentof the HPGe detectors for each measurements to be employed depending on the varieties of sample sizes (geometries) with different densities [2].Moreover to take full advantage of the large number of radionuclides whose concentration are determined from the main natural gamma-ray emitters, the efficiency should be known at least from 31.00keV to 2.50 MeV, associated with the decay products of the ^{238}U and ^{232}Th decay series [3].

In order to perform accurate and reliable activity measurements, periodical calibrations of the gamma-ray spectrometry installations of the laboratories are required [4]. In accredited laboratories, the gamma-ray spectrometry method is used to perform both qualitative and quantitative radioactivity analysis, for solid, liquid and gaseous samples [5, 6]. A typical gamma-ray spectrometry system is composed of; a detector usually semiconductor, such as HPGe with a shielding - mainly lead, to reduce the background; high voltage power supply; electronics for signal processing (preamplifier, amplifier, multichannel analyzer); computer and dedicated software [7].

The spectrometric system actually records, stores and processes the gamma-ray spectrum of any analysed sample, using validated computer software packages [8, 9]. This means that a proper energy and efficiency calibration is needed [10] to identify the energy of the gamma ray emissions from the spectrum or the gamma-ray emitter radionuclides contained by the sample (qualitative analysis). The quantitative analysis or the activity and its standard uncertainty determination for each of the radionuclide present in the sample, requires a full-energy peak efficiency (FEPE) calibration[11]. For energy and source based efficiency calibrations, various radioactive standard sources with certified activity are required.

The high resolution HPGe detector in CARST is suitable for samples containing many radionuclides from the natural radioactive series when the gamma-ray spectrum presents a large number of peaks to be resolved. These detectors are usually kept at very low temperatures (in liquid nitrogen) for a correct functioning. The detectors perform faster in analysis due to the high efficiency advantage.

This work is aim at obtaining the energy calibration and parameters of the second degree polynomial equation and comparison of the Laboratory SOurceless Calibration Software (LabSOCS) and source-based efficiency curves generated. It also investigates the differences inefficiency curves generated due to variation of source heights by~ 1.76% and ~10.07% from the actual source height using the simulated LabSOCS.

Experiment:-

The energy calibration implies the experimental determinations of a function of either first or second degree polynomial, describing the energy dependence of the channel number in the spectrum as:

$$E_\gamma = a + b \times ch + c \times ch^2 \qquad 1.0$$

where E_γ is the gamma-ray energy, ch is the channel with the maximum number of counts, $a, b, and\ c$ are constants to be determined for calibration.

The energy calibration is performed manually (cursor, marker) or automatically by the software, by measuring one or several radioactive standard sources emitting gamma-rays of minimum of three to seventeen different energies covering a wide spectral range between 31.00keV and 2.50 MeV.

In the approach of efficiency generation using LabSOCS, the materials have been developed using the geometry composer feature of Canberra's Genie™ 2000 Version 2.0 and Gamma Analysis Version 2.0A software packages. The container matrix material for the marinelli beakerwas simulated for polypropylene with chemical composition of 14.37% H, 85.63% Cand 100% C_3H_6 from the materials library filewith a default density of 0.91 g/cc. As shown in Table 1.0, the customized beaker files were created to accurately define the inner and outer wall contours, the material, and density value of the container. These files were created using a standard text editor and stored as one of the "beaker" templates in the geometry composer window torepresents the marinelli beakers available in CARST.

Table 1.0: Dimension entered in simulating the marinelli beaker and soil-like source

Description	d.1 (cm)	d.2(cm)	d.3(cm)	d.4 (cm)	Material	Density (g/cc)
Container	0.25	1.35	9.00	7.50	polypropylene	0.91
Source heights	d_1, d_2, d_3	-	-	-	Soil	1.40
Source-detector	0.15	-	-	-	-	-

10.04cm=d_1 (LabMBkr1.ECC), 10.22cm=d_2 (LabMBkr2.ECC), 11.25cm=d_3(LabMBkr3.ECC)

Table 1.0 shows a detailed description of the parameter values used to define the dimensions and material composition of the container, sample matrix and source-to-detector distance. For the sample model described, the LabSOCS Version 4.0 software was used to generate a set of mathematically calculated efficiency values for a specified set of energy values entered for 31.00keV (^{133}Ba) to 1408.01keV (^{152}Eu) with appropriate corresponding percentage uncertainty values ranging from 10% at low energies to 4% at high energies. A customized energy list createdwas stored as a text file. The detector of diameter (6.21 cm) with characterization file was created and used for theLabSOCSmodelling and efficiency calculations.

From the menu bar, theEdit/Efficiency/parameter; Edit/Efficiency/validate geometry and Edit/Efficiency/generate data point options were followed sequentially. The efficiency data were generated for each ofthe source heights 10.04 cm (d_1), 10.22 cm (d_2) and 11.25 cm (d_3) respectively as shown in Fig. 1.The Gamma Acquisition and Analysis (GAA) window was launched, and a pre-existing CAM file datasource opened in the GAA window.

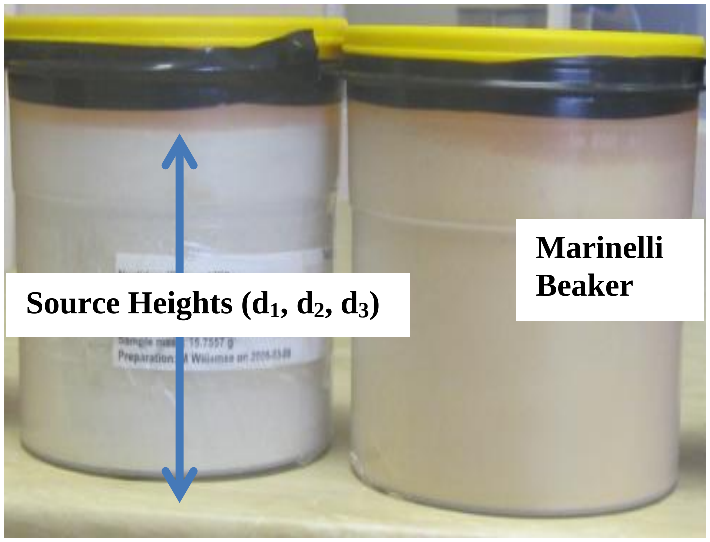

Figure 1.0: Demonstration of source heights (d1, d2, and d3).

The Calibrate|Efficiency|ByEntry option was selected from the GAA window menu bar and each efficiency data with the respective uncertainty values were entered in the displayeddialog boxopened and the 'show' action button was used to display the Dual, Empirical and Linear efficiency curves. The orders of the polynomial for the efficiency curve types were modified as necessary to achieve the best curve fits. The 'report' action button was used to generate a one-page report of the LabSOCS efficiency results. The "Calibrate/Store action button was used to save the results as a standard Genie 2000 efficiency calibration file in the Genie2k\Calfiles folderand the finish action button was used to close the dialog box to return to the GAA window. The CALfiles created were then opened as a CAM file data-source in the GAA window and the Calibrate|Efficiency and the'show' option was selected from the menu bar,followed by the 'print action' button to generate printed plots of the appropriate efficiency curve. From the reports generated, each of the data values were manually copied into the Microsoft excel spread sheet for further analysis.

For the source-based, the efficiency data were generated using the radioactive standard sources (^{133}Ba and ^{152}Eu) with gamma-ray emissions covering the wide energy range. For a given peak corresponding to the energy in the gamma-ray spectrum measured with the HPGe detector, the efficiency ε and its expanded standard uncertainty were computed as follows [12]:

$$\varepsilon = \frac{(N_{PA} - N_{BPA}) \times F_D}{T \times G_I \times A_{STD} \times F_C \times F_T} \qquad 2.0$$

where N_{PA} and N_{BPA} are the net areas of the considered peak from the gamma-ray spectrum of the in house soil standard and the net background peak area of the respective spectrum generated, T is the measurement time (the same for standard and background, expressed in seconds),F_C, F_T and F_D are the multiplicative coefficients for coincidence summing corrections, efficiency transfer corrections and for the decay during the reference time and the time the sample measurement started (important only for short half-life radionuclides),G_I is the emission probability of the considered gamma-rays and A_{STD} is the activity of the in house soil standard, expressed in Becquerel. The uncertainty in using equation 2.0 was evaluated as follows:

$$U_{\varepsilon} = \sqrt{S^2_{N_{PA}-N_{PBA}} + U^2_{G_I} + U^2_{A_{STD}} + U^2_{F_D} + U^2_{F_C} + U^2_{F_T} + U^2_T} \qquad 3.0$$

where U_{ε} is the efficiency combined standard uncertainty, $S^2_{N_{PA}-N_{PBA}}$ is the result of the net peak area (background subtracted) counts measurement uncertainty, while $U^2_{G_I}$, $U^2_{A_{STD}}$ and $U^2_{F_C}$, are the results of the measurement uncertainties for the gamma emission probability, activity and correction factors for coincidence summing, $U^2_{F_T}$ is measurement uncertainties for efficiency transfer, $U^2_{F_D}$ is measurement uncertainties for decay during the reference time and the time of the measurement start and U^2_T is measurement uncertainties of the time. However, the standard uncertainty of the measurement time and the corresponding decay are considered negligible (=1) in this work.

The mixed-gamma (^{133}Ba and ^{152}Eu) standard (soil matrix form) in the 1 litre marinellibeaker was counted until satisfactory counts (approximately 20,000) in each certificate peak criteriawere recorded [13]. The efficiency calibration calculations were performed using the GAA Calibrate|Efficiency|By Certificate File option from the GAA menu bar and the report printed. From the reports printed, all the data points corresponding to the gamma peak lines from the certificate file were manually transferred to the Microsoft excel spread sheet for comparisons.

3.Result and discussions:-

Form the energy versus channel calibration, we obtained the relationship with the values of parameters; a, b, and c from the equation (Energy = 0.7246 + 3.0259 ch +2.0 x 10^{-06}ch^2) as showed in Figure 2.0. The linear relationship following the regressive line showed a value of R^2 to be 1.00with 100% confidence.

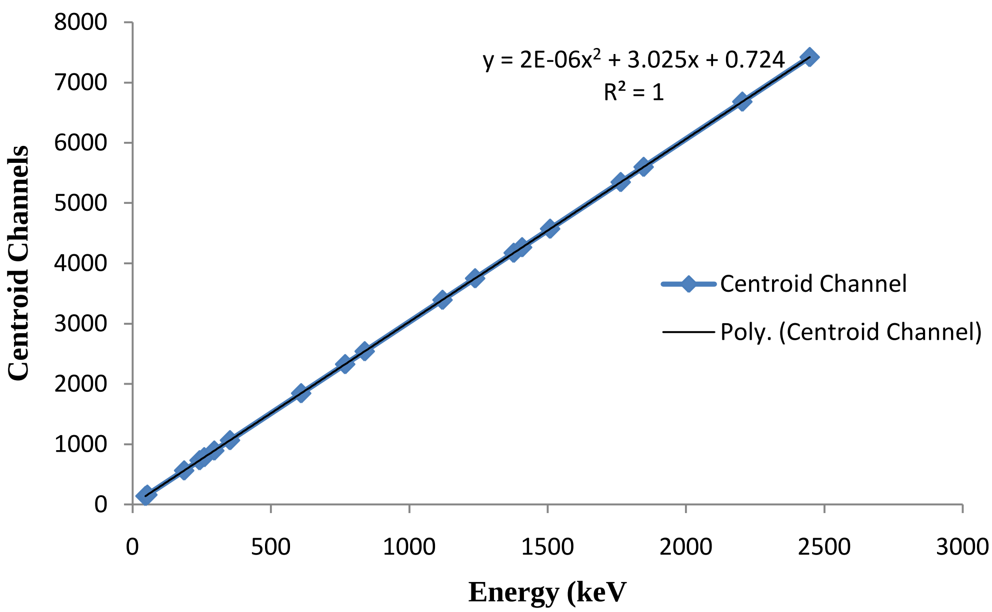

Figure 2.0: Channels versus energy calibration.

The efficiency curvesgenerated were limited to the geometries of identical matrices and different source heights as shown in Figure 3.0. The comparison was related to the source height of 10.22 cm (d_2). The efficiency curves obtained from theLabSOCSand the source base (Figure 3.0) shows that, almost all the data points agreed with +96.3% confidence intervals.

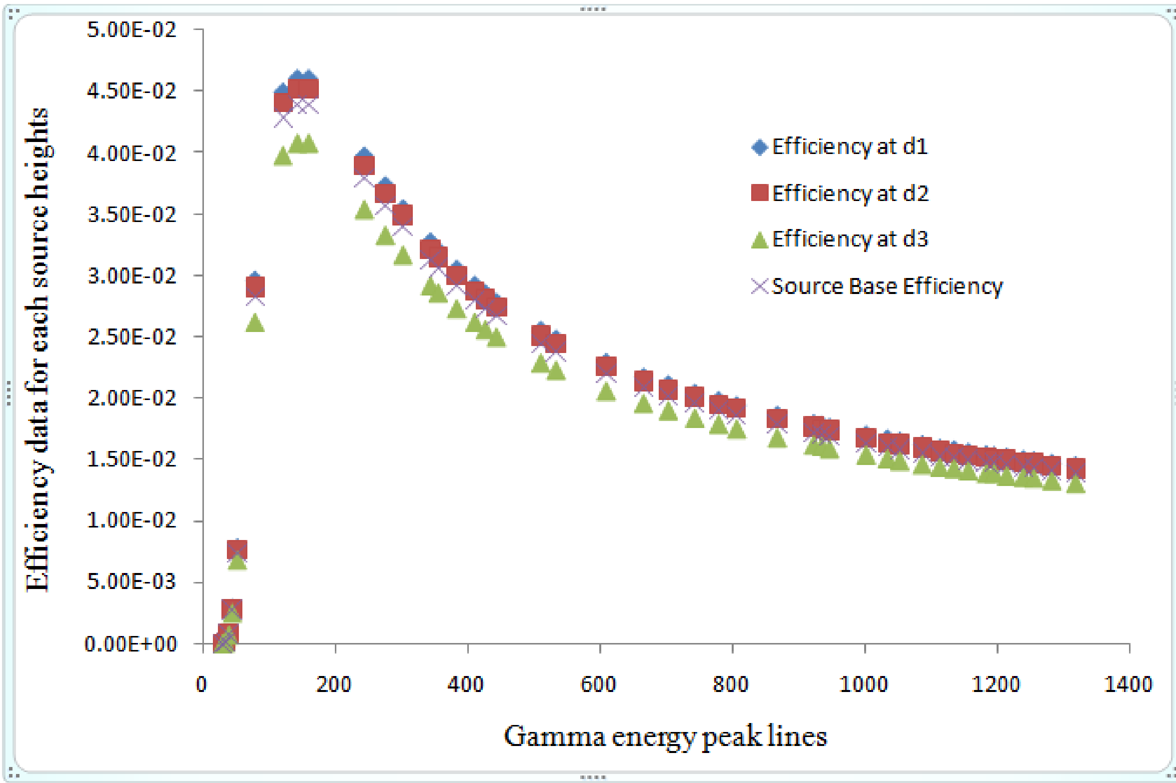

Figure 3.0: Efficiency curve at d_1, d_2, d_3 and the mixed source base standard.

This confirms that the LabSOCS efficiency calibration technique produces efficiency values which agree with source-based efficiency calibrations for the marinelli beaker containers. Therefore, employing LabSOCSfor efficiency curves generation will be adopted in CARST and this will reduce costs associated with purchase, maintenance and disposal of radioactive standard sources. In addition, the LabSOCS technique, using the 'geometry composer', will enable researchersto produce assay-grade measurements of unique sample/matrix/container samples such as water, soil, gravel, sediments, sand and certain biological samples faster.

Also, the efficiency curves of the different source heights obtained from LabSOCS are shown in Fig. 3. From the curves, it is evidence that slight misjudgements of source height from the actual, will either reduced by ±1.4 to ±2.79 % or increased by ±8.69 to ±16.32 %. Hence, homogeneity in sample matrix (sample texture), sample heights and container types, counting time and other physical parameters must be adhered to in order to obtained credible results.

4. Conclusion:-

This work describes a comparison of two gamma-ray efficiency determination methods; - Canberra's LabSOCS (Laboratory SOurceless Calibration Software) and the source-based efficiency calibrations usingmarinelli beaker sample container geometry. LabSOCS geometry modelling was developed using the geometry composer feature of Canberra's Genie™ 2000 version 2.0 and Gamma Analysis version 2.0A software packages. The efficiency data generated for each source height 10.04 cm, 10.22 cm, and 11.25cm shows variation with respect to the actual source height 10.22 cm. Based on the actual height of 10.22 cm, the LabSOCS efficiencies compared well with the source-based efficiencies for the marinelli beaker with confidence level of +96% for each of the energy peak lines.

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