Nature of Gamma Background Radiation and Dose-rate in Ain Shams University

S. U. EL-KAMEESY, M. S. ABDEL-WAHAB* and N. EL-FARAMAWY

Physics Department, Faculty of Science, Ain Shams University, Cairo, Egypt

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A study of the background gamma radiation spectrum in Ain Shams University buildings was performed for the energy range 50 keV to 3 MeV using a hyperpure Ge-detector. The absolute dose for each gamma line was calculated and an estimation of the total absorbed dose for the detected gamma lines was obtained. Comparison with other results was also performed.

1. Introduction

The gamma-ray background radiation is associated with the decay of naturally occurring radioactive isotopes that are always present in our surroundings. The nature of background radiations has been studied by many authors (Raeside and Brnetich, 1971; Camp et al., 1974; Zaits and Kuarstou, 1976; Ibrahim et al., 1981). Such studies are important in fields such as activation analysis and dating purposes for the identification of different artifacts. Since some nuclear science applications are to be started at Ain Shams University in Cairo and since the University is planning to install a radioactive laboratory for biological, clinical and physical studies, it was believed necessary to investigate the nature of the gamma background radiation. In addition to the environmental value of this study, the results obtained are essential in analysing any data for any future activities.

2. Experimental

The gamma background spectrum was investigated using a high resolution gamma-ray spectrometer of energy resolution ≈2 keV at 1.33 MeV. The experimental arrangement consisted of a liquid nitrogen cooled p-type, high purity germanium detector of active volume 62.3 cm³, with a photopeak efficiency of ≈10% relative to a 3" x 3" NaI(Tl) detector.

Before determining the dependence of the detector absolute photopeak efficiency on gamma-ray energies, the relative photoefficiency of the detector was measured using the well-known gamma-ray transitions in ²⁴⁴Am, ⁵⁷Co, ⁶⁰Co, ⁶⁰Na and ²³⁸Ra. The shape of the photopeak efficiency curve of any Ge detector was found to depend on count rate for rates greater than 1000 counts/s and on source to detector distance for distances less than 25 cm (Grant, 1982; Ismail and Malaak, 1982; Abou-Leila et al., 1979). Accordingly, the values of the source activities were chosen to give counting rates less than 1000 counts/s at source to detector distance = 25 cm.

The relative photopeak efficiency was then calculated using the formula:

\[ \epsilon_r = \frac{A_r/I_r}{A_o/I_o} \]

where \( \epsilon_o \) = efficiency of the detector for energy \( E_o \), which was taken to be equal to 1; \( \epsilon_r \) = efficiency of the detector for energy \( E_r \), relative to that of \( E_o \); \( A_r \) and \( A_o \) = net photopeak areas corresponding to energies

\[ \text{Efficiency} = 10^{10} \]

\[ E (\text{keV}) \]

\[ 0 \quad 400 \quad 800 \quad 1200 \quad 1600 \quad 2000 \quad 2400 \]

Fig. 1. Absolute and relative efficiency-energy curves.
$E_o$ and $E_i$, respectively; $I_o$ = intensity of $E_o$ (considered to be unity); $I_i$ = intensity of $E_i$. The net photopeak area was obtained in terms of the total number of counts above the base line which connects the selected boundary points. Also the total number of counts under each peak was obtained using a least squares computer fitting of the data to a Gaussian function. The obtained results of both methods agree quite well with each other.

The relative photopeak efficiency-energy curves obtained for each of the sources used in the study overlap with each other at certain energies and thus
Gamma background and dose rate

were normalized to each other to obtain the complete relative photopeak efficiency of the detector as a function of energy. The detector efficiency for the 609 keV transition was taken as unity.

Several calibrated sources with known activities were used to determine the absolute efficiency of the detector as a function of energy. The sources were $^{24}$Am, $^{10}$Co, $^{60}$Co, $^{22}$Na and $^{137}$Cs. They were placed at a distance of 25 cm from the detector. The absolute efficiency of the detector for each gamma-ray energy was then calculated from the well-known formula

$$A = 3.7 \times 10^{10} \times \frac{a}{I} \times \frac{d\Omega}{4\pi} \times E$$

where $A =$ net photopeak area; $a =$ activity of the source in Ci; $I =$ absolute intensity of the gamma transition; $d\Omega =$ solid angle increment; $E =$ absolute efficiency.

The absolute efficiencies for the above gamma energies were used to normalize the obtained relative efficiency--energy curve to yield the absolute efficiency--energy curve of the detector as shown in Fig. 1.

However, for background measurements, gamma-rays impinge on the whole surface of the detector and from all different angles. So it was necessary to find the dependence of the detector efficiency on the angle. Consequently measurements were made by placing a $^{60}$Co source at different angles in the range 0-180° from the detector window (Al-Houty et al., 1987). It was found that the detector efficiency decreases as the angle increases. Since the angular distribution of
gamma-rays is random in background measurements, it was thought to take the average value of the efficiency dependence on angle as a good approximation. The average value obtained was found to be 0.89; consequently all absolute efficiency values should be multiplied by that factor.

3. Results and Discussion

The results from the measured spectra in the physics staff research laboratory situated in one floor building in Ain Shams University are shown in Fig. 2, where the energies are in keV. In these spectra, 57 well-resolved gamma lines were observed in addition to 5 other lines designated as x-rays. The energies of these lines as well as their respective net photopeak areas are tabulated in Table 1 where each gamma line is labeled to the parent radioactive isotope. The net photopeak area for each gamma line was corrected for the dependence of the photopeak absolute efficiency on the energy. The identification of these gamma lines indicated that the results are from nine radiative isotopes. Eight of these radionuclides: $^{214}$Bi, $^{214}$Pb, $^{226}$Ra, $^{228}$Th, $^{208}$Tl, $^{212}$Bi, $^{237}$Ac, belong to two well-known naturally occurring radioactive series, while the ninth radionuclide is the naturally occurring $^{40}$K. The presence of these radioactive nuclides is in accordance with other previous measurements except for $^{137}$Cs, $^{210}$Pb (Zaits and Kuastsou, 1976; Ibrahim et al., 1981; Al-Houty et al., 1987).

The absorbed dose rate for each gamma line was calculated using the equation

$$Dose\ rate = \frac{\phi E(\sigma/\rho)}{62,500 \text{ MeV/g-mrad mrad/s}},$$

where $\phi$, flux density (photons/s • cm$^2$); $E$, energy of the gamma photon in MeV; $\sigma$, the energy absorption coefficient; $\rho$, density of the media.

The density of tissue was considered to be approximately as water and the absorbed dose rate for each gamma line was calculated using the data of the absolute counts, the surface area of the detector and the energy absorption coefficient curve (Dwight, 1972). The results are shown in Table 1.

The sums of the dose rate in units of nGy/d for the detected gamma lines belonging to elements of each of the three naturally occurring series as well as the $^{40}$K are summarized in Table 2. It is clear from Table 2 that the uranium and thorium series are comparable in their contributions to background. In order to compare the results obtained in this work with those of previous measurements (Zaits and Kuastsou, 1976; Ibrahim et al., 1981), where no
Table 2. Dose rate (nGy/d) of present work compared with previous 
data

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<td>19.75</td>
<td>14</td>
<td>30</td>
<td>18</td>
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<td>Th</td>
<td>16.22</td>
<td>11</td>
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<td>25</td>
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<td>Ac</td>
<td>--</td>
<td>10</td>
<td>10</td>
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<td>40K</td>
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<td>10</td>
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<td>37</td>
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<td>47.99</td>
<td>35</td>
<td>90.9</td>
<td>79.9</td>
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correction for the photopeak efficiency was done, it was necessary to normalize all results for the effect of detector volume (Vano et al., 1975). For the Ge detector the relative efficiency at 1.33 MeV can be approximated by multiplying by 0.2 the active volume in cm$^3$ (Martini, 1981). The active volume of the detector used by Zaits and Kuarstsou (1976) was 47 cm$^3$ and that of the detector used by Ibrahim et al. (1981) was 62.35 cm$^3$ while that of the detector used by Al-Houty et al. (1987) was 56.4 cm$^3$. The one used in this work was 62.3 cm$^3$.

The normalized total net photopeak areas of the detected gamma lines belonging to the three radioactive series as well as the $^{40}$K were calculated for the results of the present work as well as for the work of Zaits and Kuarstsou (1976), Ibrahim et al. (1981) and Al-Houty et al. (1987). The ratios between these values were calculated. The dose rates for the previous results (Zaits and Kuarstsou, 1976; Ibrahim et al., 1981) and Al-Houty et al. (1987). The ratios between these values were calculated. The dose rates for the previous results (Zaits and Kuarstsou, 1976; Ibrahim et al., 1981) were then calculated approximately by multiplying the dose rates of the present work by the respective ratio for each series. The results obtained are shown in Table 2. The dose rates due to the detected gamma lines of the Ac-series are negligible in all works. The present results for the total dose rate and that of Al-Houty et al. (1987) are lower than that obtained by Zaits and Kuarstsou (1976) and Ibrahim et al. (1981). The difference in the results may be attributed to the different artificial radiation activities as well as building materials.

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References


