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Environmental Radiation Doses at King Saud University Campus

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Abstract. Measurement and analysis of gamma background radiation outside King Saud University buildings at the energy range 185 keV-3MeV using a hyper pure Ge-detector of active volume 156.6 cc were carried out. The data is corrected for the detector efficiency dependence on gamma ray energies. The absorbed dose for each gamma line was calculated and the total absorbed doses for the detected gamma lines were estimated. Comparison with other results was also performed.

Introduction

The naturally occurring radioactive series are widely distributed in the earth crust and usually secular equilibrium between parent and daughters nuclides in a given decay chain exists. Their decay products are the most important source of radiation exposure to the general public. The release of radioactive nuclides from both nuclear weapons testing and nuclear accidents has had severe effects in the nearby regions and has been the cause of public concern all over the world. Airborne radioactivity can deposit directly into the ground or be washed out by rain leading to the contamination of both vegetation and soil. Furthermore, building materials, such as bricks and concrete, have a significant contribution to natural background radiation.

To define pathways followed by radioactive nuclides in the ecosystem and assess their effect on human, many environmental and biological samples must be studied for the radioisotopes of interest. Those decaying by the emission of gamma rays are the easiest to study. Consequently, gamma ray background radiation in different countries has been previously studied by many authors [1-10].

It is believed necessary to study the nature of the gamma background radiation outside King Saud University building (in a wooden port-cabin situated in the courtyard). In addition to the environmental value of this study, the results obtained are essential in analyzing any data for possible future nuclear activity measurement .

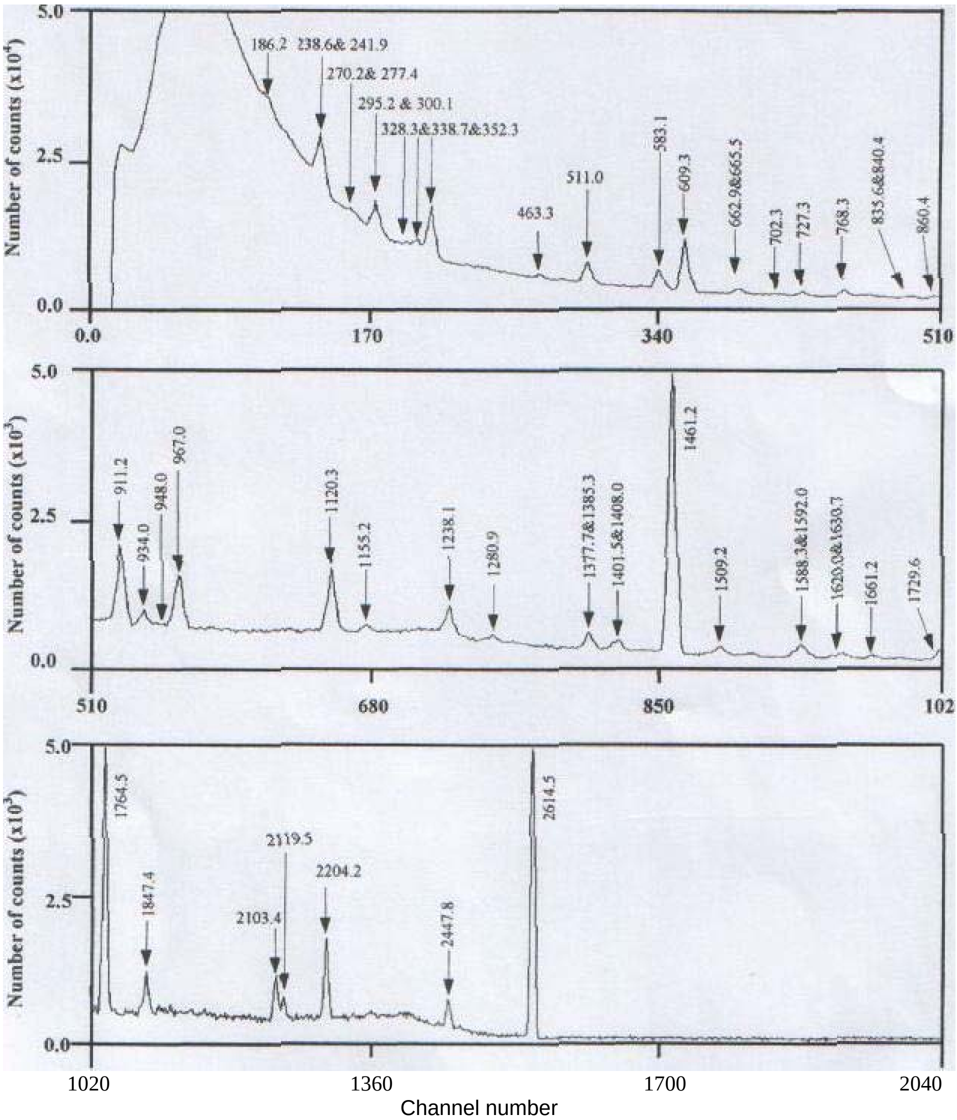

Fig. 1 (a,b,c). Gamma ray background spectrum observed outside King Saud University buildings by large (156.6 cc) hyper pure Ge-detector.

Experimental Procedure

The experimental arrangement consists of a liquid nitrogen cooled ORTEC p-type hyper pure germanium detector of active volume 156.6 cm^3 with a photo-peak efficiency $\approx$ 38% relative to a 3in x 3in Nal(TI) detector and an energy resolution $\approx$1.85keV at 1.33 MeV gamma line. The detector was coupled through an amplifier to an IBM-XT personal computer equipped with an Aptec MCA plug-in card.

The energy calibration of the spectrometer was performed using the well-known standard sources (^{22}Na, ^{60}Co, ^{88}Y, ^{137}Cs, ^{226}Ra and ^{241}Am), to cover an energy range from 60 keV to 3 MeV. In gamma-ray emission rate measurements by means of germanium spectrometers, the crucial quantity limiting the attainable accuracy is the detector efficiency. Uncertainty due to counting statistics, peak evaluation and random coincidence summing corrections can be minimized by choosing appropriate measuring conditions and evaluation procedure [11]. Accordingly, the values of the source activities were chosen to give counting rate less than 1000 counts/sec. at a source to detector distance of 25 cm [12].

The relative photo-peak efficiency of the detector was measured using the well-known gamma-ray transitions in ^{22}Na, ^{60}Co, ^{88}Y, ^{137}Cs, ^{226}Ra and ^{241}Am. It was then calculated, using the formula:

$$\frac{\varepsilon_i}{\varepsilon_0} = \frac{A_i / I_i}{A_0 / I_0} \qquad (1)$$

Where ε_0 is the efficiency of the detector at the energy E_o and is taken as unity, ε_i is the efficiency of the detector at the energy E_i relative to that of E_o, A_o and A_i are the net photo-peak areas corresponding to the energies E_o and E_i respectively, I_o is the intensity of gamma transition of energy E_o (considered to be unity) and I_i is the intensity of the gamma transition of energy E_i. The net photo-peak area was obtained in terms of the total number of counts above the background. The total number of counts under each peak was found by using a least square fit of the data to a gaussian function. The relative photo-peak efficiency-energy curve, obtained for each source used in this study overlaps with each of the other curves at certain energy. These curves were normalized to each other to obtain the complete relative photo-peak efficiency of the detector as a function of energy.

The detector efficiency at the 609.3 keV transition is taken to be unity. The absolute efficiency of the detector ε, as a function of energy was then calculated using the relation below for each gamma energy:

$$A_{\omega} = 3.7\times10^{10}\times a\times I\times\frac{d\Omega}{4\pi}\times \qquad (2)$$

Where A is the net count rate; a is the activity of the source in Ci; I is the absolute intensity of the gamma transition and $d\Omega$ is the solid angle increment.

The absolute efficiencies for the known energies were used to normalize the obtained relative efficiency-energy curve to yield the absolute efficiency-energy curve of the detector.

In background measurements, gamma rays impinge on the surface of the detector from different angles and hence it was necessary to find the detector efficiency dependence on the angle. This dependency was studied by placing a ^{60}Co source at different angles in the range of 0^o to 180^o from the detector window. It was found that the detector efficiency decreases as the angle increases. Since the angular distribution of gamma rays is random in background measurements, the average value of the efficiency dependence on the angle was taken as a good approximation [3]. The same procedure was done in this work and a correction factor of an average value of 0.92 is found. Therefore, the absolute efficiency values were multiplied by this factor.

Results and Discussion

Measurements of the gamma background radiation in a wooden port-cabin (with an asphalt flooring) situated in King Saud University courtyard have been repeated several times during a period of three months. The time of each measurement was 90 hours. It was found that the fluctuations in the measurements do not exceed the inherent statistical fluctuation of the measurement itself. An example of the measured spectra is shown in Fig. 1(a,b,c).

In these spectra, well-resolved gamma lines were observed. The energy of each line as well as its respective intensity and its parent radioactive isotope are tabulated in Table 1.

Table 1 also includes the results of a previous study of background radiation measurement in the nuclear research laboratory, situated in the ground floor of the two-floor building in King Saud University [8].

The net photo-peak area for each gamma line was corrected for the dependence of the photo-peak absolute efficiency on the energy.

The identification of these gamma lines proved the presence of nine radioactive isotopes. Eight of these radio-nuclides ^{214}Bi, ^{214}Pb, ^{226}Ra, ^{234}Th, ^{208}Tl, ^{212}Pb, ^{212}Bi and ^{228}Ac, belong to the two well-known naturally occurring radioactive series, (Uranium and Thorium series) while the ninth radio-nuclide is the naturally occurring ^{40}K.

Table 1. The gamma ray energies, their parent isotope; intensities and the absorbed doses in the observed background spectra in King Saud University building

Energy (keV)	Parent isotope	Present work		Garawi (2000)	
		Intensity (photons/s)	Abs. Dose (pGy/d)	Intensity (photons/s)	Abs. dose (pGy/d)
186.2	^{226}Ra	0.02245	10.0	0.087	32
209.6	^{228}Ac	-	-	0.020	10
238.6	^{212}Pb	0.0227	93.9	0.380	157
241.9	^{214}Pb	0.096	54.18	0.100	56
270.2	^{228}Ac	0.01	12.39	0.010	12
277.4	^{208}TI	0.009	6.21	0.009	5
295.2	^{214}Pb	0.142	96.7	0.320	221
300.1	^{212}Pb	0.062	83.35	0.06	41
328.3	^{228}Ac	0.013	10.75	0.026	22
338.7	^{228}Ac	0.097	55.9	0.084	72
352.3	^{214}Pb	0.43	385.9	0.64	573
463.3	^{228}Ac	0.031	36.5	0.028	33
511.0	$^{208}\mathrm{T}\ell$ + an	0.18	270.0	0.210	315
583.1	$^{208}\mathrm{T}\ell$	0.30	44.4	0.250	370
609.3	^{214}Bi	0.82	395.1	1.00	1702
662.6	^{214}Bi	0.92	155.4	0.110	185
665.5	^{214}Bi	0.009	15.55	0.060	101
702.7	^{214}Bi	0.009	77.6	0.024	233
727.3	^{212}Bi	0.095	83.6	0.050	92
768.3	^{214}Bi	0.095	177.9	0.150	281
786.1	^{214}Pb	-	-	0.037	71
795.0	^{228}Ac	-	-	0.048	86
806.0	^{214}Bi	-	-	0.030	59
835.6	^{228}Ac	0.008	90.9	0.015	29
840.4	^{228}Ac	0.013	36.8	0.030	59
860.4	^{208}T1	0.035	71.9	0.052	105
911.2	^{228}Ac	0.34	734.1	0.350	747
934.0	^{214}Bi	0.07	162.4	0.130	285
948.0	^{228}Ac	0.005	12.2	0.089	24
967.0	^{228}Ac	0.098	131.0	0.058	131
1000.0	^{228}Ac	-	-	0.040	115
1052.0	^{214}Bi	-	-	0.003	8
1120.3	^{214}Bi	0.621	163.1	0.910	239
1155.2	^{214}Bi	0.066	180.3	0.130	352
1207.7	^{214}Bi	-	-	0.033	95
1238.1	^{214}Bi	0.43	129.3	0.44	1277
1280.9	^{214}Bi	0.075	225	0.100	300
1377.7	^{214}Bi	0.29	987	0.29	987
1385.3	^{214}Bi	0.012	32.5	0.060	195
1401.5	^{214}Bi	0.1	299.1	0.110	329
1408.0	^{214}Bi	0.154	505.6	0.180	591
1461.2	^{40}K	6.6	20775	6.650	20905
1496.2	^{228}Ac	-	-	0.018	8
1509.2	^{214}Bi	0.027	103	0.150	560
1580.8	^{228}Ac	-	-	0.060	236
1588.3	^{228}Ac	0.021	77.0	0.074	267
1592.0	^{212}Bi	0.08	270	0.078	252

Table 1. *Contd.*

Energy (keV)	Parent isotope	Present work		Garawi (2000)	
		Intensity (photons/s)	Abs. dose (pGy/d)	Intensity (photons/s)	Abs. dose (pGy/d)
1620.0	^{212}Bi	0.08	280.3	0.098	341
1630.7	^{228}Ac	0.082	290.1	0.030	105
16661.2	^{214}Bi	0.058	207	0.058	207
1729.6	^{214}Bi	0.22	217	0.220	817
1764.5	^{214}Bi	0.295	1120.7	0.820	3109
1838.8	^{214}Bi	-	-	0.025	98
1847.4	^{214}Bi	0.176	699.2	0.160	635
1873.2	^{214}Bi	-	-	0.023	85
2103.4	^{208}T1	0.22	904	0.110	452
2119.5	^{214}Bi	0.066	275.2	0.085	351
2204.2	^{214}Bi	0.37	1593	0.370	1593
2292.2	^{214}Bi	-	-	0.023	104
2447.8	^{214}Bi	0.11	534	0.114	548
2614.5	$^{208}T\ell$	1.48	7678.7	0.830	4239

The absorbed dose rate for each gamma line at 1.5 m above the floor was calculated using the equation [13].

$$\text{Dose rate} = \frac{jE(\sigma/\rho)}{62500\ \text{MeV/g.mrad}}\ \text{mrad/s} \qquad (3)$$

Where: φ, E, σ, ρ are the flux density (photons/sec. Cm^2): energy of the gamma photon in MeV; energy absorption coefficient and density of the media respectively. The total surface area of the detector was considered in calculating the flux density for each gamma transition.

Considering the density of tissue to be approximately that of water and using the data of the absolute counts, the surface area of the detector and the energy absorption coefficient curve [14, p.8-204] of the doses were calculated and the obtained results are shown in Table 1.

The sums of the dose rate in units of nGy/d of the detected gamma lines belonging to elements of each of the three naturally occurring series as well as that for ^{40}K obtained in this work, together with the results of Garawi (2000) [8]; Al-Houty *et al.* (1987) [3] and El-Kameesy and Sallam (1999) [7] are summarized in Table 2.

The present measured dose rates are less than the world average. A typical range of variability for previously measured absorbed dose rates in air is from 10 to 200 nGy/h [9]. Al-Arfaj *et al.* [15] found that the average calculated dose rate in Riyadh region at 1m above soil surface from terrestrial gamma radiations is 28.1 nGy/h while the measured average value is 43.38 nGy/h.

The low detected dose rate of the present work could be attributed to the measurements at 1.5 m rather than 1m above sandy ground covered with asphalt. In addition to that the energy range 0-185 keV was not taken in our consideration.

It is clear from Table 2 that, uranium and thorium series contribution to background radiation in the present work is comparable with the corresponding results obtained by Al-Houty *et al.* (1987) [3], El-Kameesy and Sallam (1999) [7].

Table 2. The dose rates of the present work compared with other's data

Series	**Dose rates (nGy/d)**			
	Present work* KSA	**Garawi** [8] **KSA**	**Al-Houty* [3] Qatar**	**El-Kameesy*[7] Egypt**
U-series	10.848	16.55	11.0	12.0
Th-series	11.0	8.07	7.0	7.90
^{40}K	20.775	20.91	14	13.46
Total	42.623	45.53	32.	33.56

* Outside the building
** Inside the building

The same high contribution of the 1461 keV gamma line attributed to ^{40}K inside and outside King Saud University buildings was observed. Furthermore, the total dose rate inside and outside these buildings indicates that the contribution of wall constituents (bricks and concrete) to background radiation is minor. The external walls are built of concrete with large windows while the internal of these buildings are partitioned with plastic and steel sheets. The additional small contribution to the total dose inside the building may be attributed to the minimum use of concrete in these buildings.

Conclusion

Our measurement and analysis of gamma background radiation using 156.6 cc hyper pure Ge-detector led to a conclusion that the dose rates obtained are mainly due to the detected gamma lines of U-series, Th-series and ^{40}K. The dose rate of the Ac-series, is negligible in all measurements.

The contribution of ^{40}K (1461 keV gamma line) is high compared with the corresponding results in neighboring countries [3,6]. Furthermore, this study showed that there is a small contribution to the total dose may be attributed to the minimum use of concrete in these buildings. In addition to the environmental value of this study, the results obtained are essential for any future radiation dose measurement.

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الجرعات الإشعاعية البيئية في حرم جامعة الملك سعود

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ملخص البحث . أجريت القياسات و التحليل لطيف أشعة جاما الناتجة عن الخلفية الإشعاعية خارج مباني جامعة الملك سعود عند مدى من الطاقة يتراوح بين ١٨٥ كيلو إلكترون فولت إلى ٣ مليون إلكترون فولت و ذلك باستخدام كاشف جرمانيوم فائق النقاوة يبلغ حجمه الفعال ١٥٦,٦ سم^{3}و قد تم تصويب النتائج بالأخذ في الاعتبار اعتماد كفائة الكاشف على طاقات الأشعة الجامية. و تم أيضا قياس الجرعة الإشعاعية لكل خط من خطوط أشعة جاما و كذلك الجرعة الممتصة الكلية. كما تمت مقارنة النتائج الحالية و بعض الأعمال السابقة المشابهة في بلدان مختلفة.