Specific activities and radiation hazard parameters calculations of natural radionuclides in AL-Mustansiriyah university soils using NaI(Tl) detector

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Abstract

The specific activities of the natural radionuclides U-238 and Th-232 and K-40 in 14 soil samples collected from different sites from AL-Mustansiriyah university at two depths (topsoil "surface" and 20cm depth) were be investigated using gamma ray spectrometer 3"x3" NaI(Tl) scintillation detector.

The analysis of the energy spectra of the soil samples show that these samples have specific activities ranging with (16.08-51.11) Bq/kg for U-238, (14.79-52.29) Bq/kg for Th-232 and (191.08-377.64) Bq/kg for K-40, with an average values of 29.37, 34.14 and 289.62 Bq/kg for U-238, Th-232, k-40 respectively. The radiation hazard parameters of the natural radionuclides; radium equivalent activity (Ra_{eq}), gamma absorbed dose rate (D_γ), annual effective dose rate (E_γ), internal and external hazard index (H_{in}, H_{ex}) have also been calculated. The maximum value of specific activities and hazard parameters was found in the sample of the soil gathered from the Literature college center. All the calculated specific activates values were be in the ranges of worldwide averages, and below than the global permissible limits, this would indicate that the soils of the University is safety for both students and staff.

Key words

Natural radionuclides, hazard parameters, Gamma Spectroscopy.

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حساب الفعالية النوعية ومعاملات الخطورة الاشعاعية للنويدات المشعة الطبيعية في تربة الجامعة المستنصرية باستخدام كاشف ايوديد الصوديوم NaI(Tl)

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الخلاصة

تم في هذا البحث حساب الفعالية النوعية للنويدات المشعة الطبيعية U-238، Th-232 و K-40 التي تم الكشف عنها في اربعة عشر عينة جمعت من مناطق مختلفة من تربة الجامعة المستنصرية بعمقين الاول من سطح التربة و الثاني من عمق 20 سم باستخدام مطياف اشعة كاما (كاشف ايوديد الصوديوم المطعم بالثاليوم).

بينت النتائج امتلاك العينات المدروسة فعالية نوعية بحدود (16.08-51.11 Bq/kg) و (14.79-52.29 Bq/kg) و (191.08-377.64 Bq/kg) وبمعدل 29.37، 34.14، 289.62 Bq/kg لكل من اليورانيوم-238 والثوريوم-232 والبوتاسيوم-40 على التوالي. تم ايضا حساب معاملات الخطورة الاشعاعية والفعالية المكافئة للراديوم ومعدل الجرعة الممتصة لاشعة كاما ومعدل الجرعة السنوية الفعالة ومعامل الخطورة الداخلي والخارجي لجميع العينات قيد الدراسة. لوحظ ان اعلى قيمة للفعالية النوعية ولمعاملات الخطورة الاشعاعية كان في عينة التربة التي جمعت من حديقة كلية التربية. وقد امتلكت جميع العينات المفحوصة قيم فعالية نوعية ومعاملات خطورة اشعاعية ضمن المديات العالمية المسموحة مما يدل على ان تربة الجامعة المستنصرية امنه لكل من الطلبة والتدريسين والعاملين في الجامعة.

Introduction

People were always exposed to natural radiations which emanate from the interior and the exterior of the earth, The exposure to the ionizing radiations from natural sources occurs because of the radioactive elements that naturally occur in soil and in rocks, the cosmic rays which penetrate from space into the earth's atmosphere and the internal exposure to radioactive elements through food, water and air [1].

Usually, radionuclides have accumulated on the surface of all ground, and 85% of them are retained at a depth 5cm [2]. There are great differences in the vertical distribution of the radiological contamination of soil, and also between arable and non-arable agricultural surfaces. The natural radioactivity in the soil samples originated from series of U-238 and Th-232 and natural K-40 so that usually the contents of U-238 and Th-232 and K-40 are being determined [3].

In addition to being the main source of continuous radiation exposure to human, soil acts as a medium of migration for the transfer of radionuclides to the biological systems and hence, it is the basic indicator of radiological contamination in the environment. Moreover, the soil radioactivity is usually important for the purposes of establishing baseline data for future radiation impact assessment, radiation protection and exploration [4]. The dose rates vary from one place to another depending upon the concentration of natural radionuclides such as U-238, Ra-226, Th-232 and K-40 present in soil. These radionuclides pose exposure risks externally due to their gamma-ray emissions and internally due to radon and its progeny that emit alpha particles [5]. The radionuclides present in soils can pass on to the food chain and the air, contributing to the internal dose received by the population [6].

Samples collection and preparation

Soil samples at two depths of (0-20cm) were collected during 2013 from fourteen different locations of the Al-Mustansiriyah University. After removing the stones and impurities, the soil samples were dried in oven at 150^o for 24h and grinded sifted (with mesh having 630 μm) and homogeneous. About 1kg weight of each sample was kept and sealed in a special plastic Marinelli beaker and left for 30 days to reach radioactive equilibrium where the rate of decay of the daughter becomes equal to that of the parent as shown in Fig. 1. The location of the sites from which the soil samples were collected were shown in Fig. 2. The longitude and latitude positions of the area of the collected samples have been detected by (GPS) system are listed for each sample code, location and depth in Table 1.

Fig. 1: Marinelli beaker filled with soil samples.

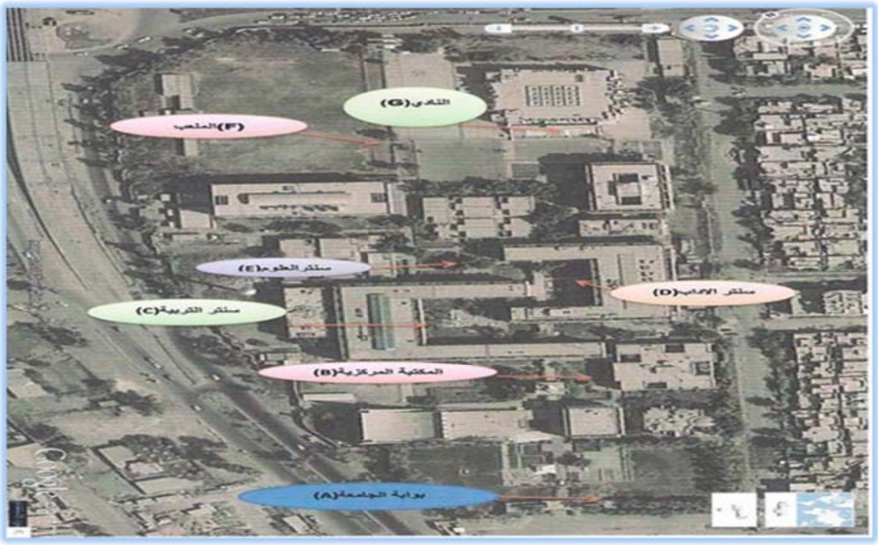

Fig. 2: A section of Al-Mustansiriyah University map mention the name and the location of the sites from which the soil samples were collected.

Table 1: Sample code, location, depth, longitude and latitude for each sample.

No.	Sample Code	Sample Location	Sample Depth	Longitude	Latitude
1	A1	Near the door of the university	Surface	33°21′55″	44°24′04″
2	A2	Near the door of the university	20 cm	33°21′55″	44°24′04″
3	B1	Near the Central Library	Surface	33°21′59″	44°24′06″
4	B2	Near the Central Library	20 cm	33°21′59″	44°24′06″
5	C1	Center College of Education	Surface	33°22′00″	44°24′07″
6	C2	Center of College Education	20 cm	33°22′00″	44°24′07″
7	D1	Center of College Arts	Surface	33°22′00″	44°24′09″
8	D2	Center of College Arts	20 cm	33°22′00″	44°24′09″
9	E1	Center of College Sciences	Surface	33°22′02″	44°24′09″
10	E2	Center of College Sciences	20 cm	33°22′02″	44°24′09″
11	F1	Near University Stadium	Surface	33°22′05″	44°24′11″
12	F2	Near University Stadium	20 cm	33°22′05″	44°24′11″
13	G1	Near the student club	Surface	33°22′04″	44°24′15″
14	G2	Near the student club	20 cm	33°22′04″	44°24′15″

Radioactivity measurements

The measurements were based on the recording natural radioactivity quantities of three natural long-lived elements U-238 and K-40 which are considered the photo peaks at (1760,2614keV) and (1460keV) respectively, the concentration of Tl-208 and Bi-214 occur in the samples due to disintegration of U-238 and Th-232 respectively, therefore the activities of Tl-208 and Bi-214 in the samples indicates the presence of U-238 and Th-232 respectively.

- **Specific activities calculation**

To investigate the specific activates of the detected radionuclides in the samples, the empty and filled with soil (Marinelli beakers) were put on the NaI(Tl) 3"×3" crystal of the detector sequentially for a period of four hours (14400sec) with operating voltage

(650V), to get gamma spectrums of the background of the laboratories and the samples. Fig. 3 shows the gamma spectroscopy system.

The specific activities of the radionuclides were calculated from the equation [7]:

$$Specific\ Activity\ (Bq) = \frac{Net\ peack\ area\ (counts)}{Eff.\%*I_\gamma*W*T} \quad (1)$$

where: *(Eff.)* is the efficiency of specific energy, (I_γ) is the intensity of emitted gamma-ray(%), W: sample weight in (kg),and T: measuring time (s).

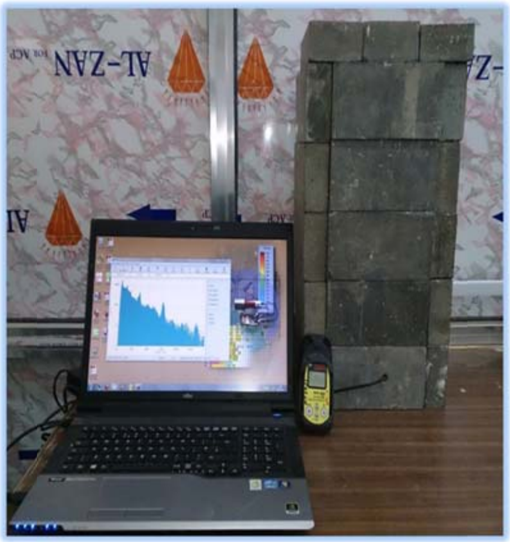

Fig. 3: NaI(Tl) gamma spectroscopy system.

- **Efficiency calibration curve**

The efficiency curve was managed by accumulated the gamma ray spectrum for a mixing of three standard point sources of known activity and different gamma energy peaks, Ba-133(356.1 keV), Cs-137(661.9keV) and Co-60(1173.2 and 1332.5keV). The time of accumulated spectrum was (14400s) and the efficiency of each source would be calculated by Eq. (1).

- ***Hazard Radiation Parameters***

Radium equivalent (R_{eq}), gamma absorbed dose (D_γ), annual effective dose(E_{out}) External Hazard Index (H_{ex}) and Internal hazard index (H_{in})were calculated for all samples from the following equations respectively [8]:

$$Ra_{eq} = A_U + 1.43\ A_{Th} + 0.077 A_K \quad (2)$$

$$D_\gamma = 0.462\ A_U + 0.604\ A_{Th} + 0.0417\ A_K \quad (3)$$

$$E_{out}(\text{mSv/y}) = D_\gamma(\text{nGy/h}) \times 10^{-6} \times 8760\ \text{h/y} \times 0.20 \times 0.7\ \text{Sv/Gy} \quad (4)$$

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \leq 1 \quad (5)$$

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \leq 1 \quad (6)$$

where A_U, A_{Th} and A_K are the specific activities of U-238, Th-232 and K-40 respectively.

Results and discussion

The specific activities calculated for the three natural radionuclides detected in the 14 soil samples have the range of (16.08-51.11Bq/kg) for U-238, (14.79-52.29Bq/kg) for Th-232 and (191.08-377.64Bq/kg) for K-40, with an average values of (29.37, 34.14 and 289.62 Bq/kg) for U-238, Th-232 and K-40 respectively as shown in Table 2.

The radiation hazard parameters were be calculated and listed in Table 3 and Figs.4, 5, 6 which is shown the following:

1. The radium equivalent (Req) have a range of (71.28-154.96 Bq/kg) and a mean of (100.49 Bq/kg), it is less than acceptable limit (300 Bq/kg).
2. The mean absorbed gamma dose rate ($D\gamma$) have a range of

(33.30-70.94nGy/h) and a mean of (46.27Bq/kg), it is less than the world wide average value (55nGy/h).
3. The estimated annual effective dose values have a range with (0.041-0.087mSv/y) and a mean of (0.057mSv/y).
4. The external hazard index has a range of (0.193-0.419) and a mean of (0.271).
5. The internal hazard index has a range of (0.248-0.557) and a mean of (0.351).
Since the last three values are lower than unity we can say that the radiation hazards of the studying soil in this region is low and lie within the acceptable limits.

Conclusions

This study shows that the maximum value of specific activities and hazard parameters was found in the Literature college center at 20cm depth (D2 sample)which still with all other soil samples within the ranges of worldwide averages and below than the global permissible limits. This indicates that this soil in Al-Mustansiriyah University is safety for all students and staff.

The increase in specific activity that has been observed in D2 sample can be related to the radioactive isotopes including in the phosphate fertilizers that may be used for energizing the garden soil of this region.

Table 2: The specific activity of the radionuclides.

No.	Sample code	Specific Activity (Bq/kg)		
		U-238	Th-232	K-40
1	A1	36.01	22.46	253.64
2	A2	28.13	30.74	345.82
3	B1	29.17	22.96	228.26
4	B2	39.73	18.91	209.77
5	C1	31.65	29.20	191.08
6	C2	31.11	14.79	322.92
7	D1	20.61	21.46	259.46
8	D2	51.11	52.29	377.64
9	E1	17.86	46.92	348.14
10	E2	26.10	42.91	335.23
11	F1	34.87	51.06	290.96
12	F2	31.86	38.12	281.48
13	G1	16.90	48.69	292.59
14	G2	16.08	37.43	317.68
Min.		**16.08**	**14.79**	**191.08**
Max.		**51.11**	**52.29**	**377.64**
mean		**29.37**	**34.14**	**289.62**
Worldwide average[9]		**30**	**35**	**400**

Table 3: Radiation hazard parameters of the soil samples.

No.	Sample code	Hazard Radiation Parameters				
		Ra_{eq} (Bq/kg)	D_γ (nGy.h^{-1})	E_γ mSv/y	H_{ex}	H_{in}
1	A1	87.66	40.78	0.050	0.237	0.334
2	A2	98.71	45.98	0.056	0.267	0.343
3	B1	79.58	36.86	0.045	0.215	0.294
4	B2	82.93	38.53	0.047	0.224	0.331
5	C1	88.11	40.22	0.049	0.238	0.324
6	C2	77.12	36.77	0.045	0.208	0.292
7	D1	71.28	33.30	0.041	0.193	0.248
8	D2	154.96	70.94	0.087	0.419	0.557
9	E1	111.76	51.11	0.063	0.302	0.350
10	E2	113.26	51.95	0.064	0.306	0.376
11	F1	130.29	59.08	0.072	0.352	0.446
12	F2	108.05	49.48	0.061	0.292	0.378
13	G1	109.06	49.42	0.061	0.295	0.340
14	G2	94.06	43.28	0.053	0.254	0.297
Min.		**71.28**	**33.30**	**0.041**	**0.193**	**0.248**
Max.		**154.96**	**70.94**	**0.087**	**0.419**	**0.557**
mean		**100.49**	**46.27**	**0.057**	**0.271**	**0.351**
Worldwide Average[10]		**300**	**55**	**1**	**1**	**1**

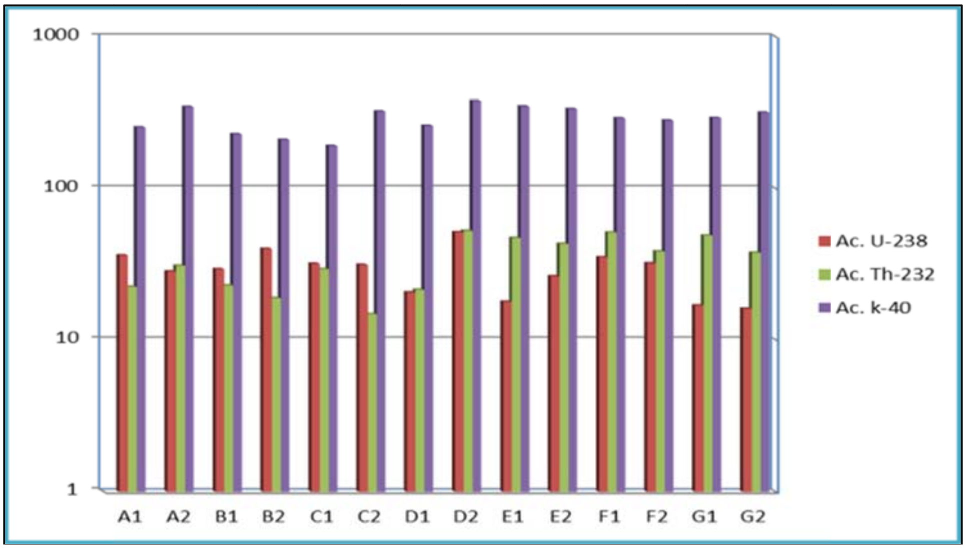

Fig. 4: Specific activity of uranium, thorium and potassium in each sample.

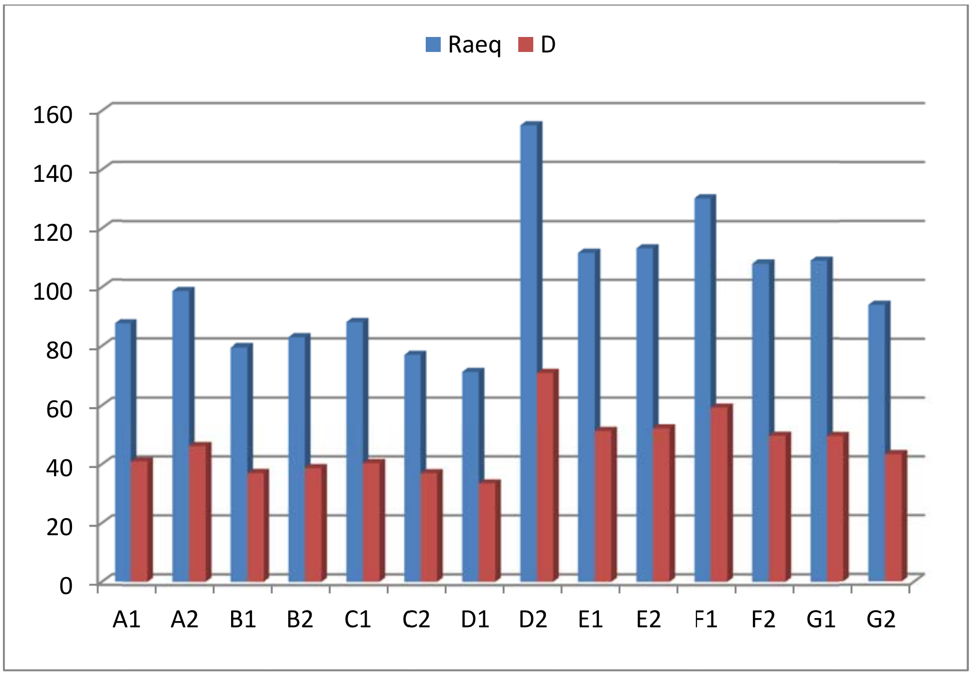

Fig. 5: Radium equivalent and absorbed dose for each sample.

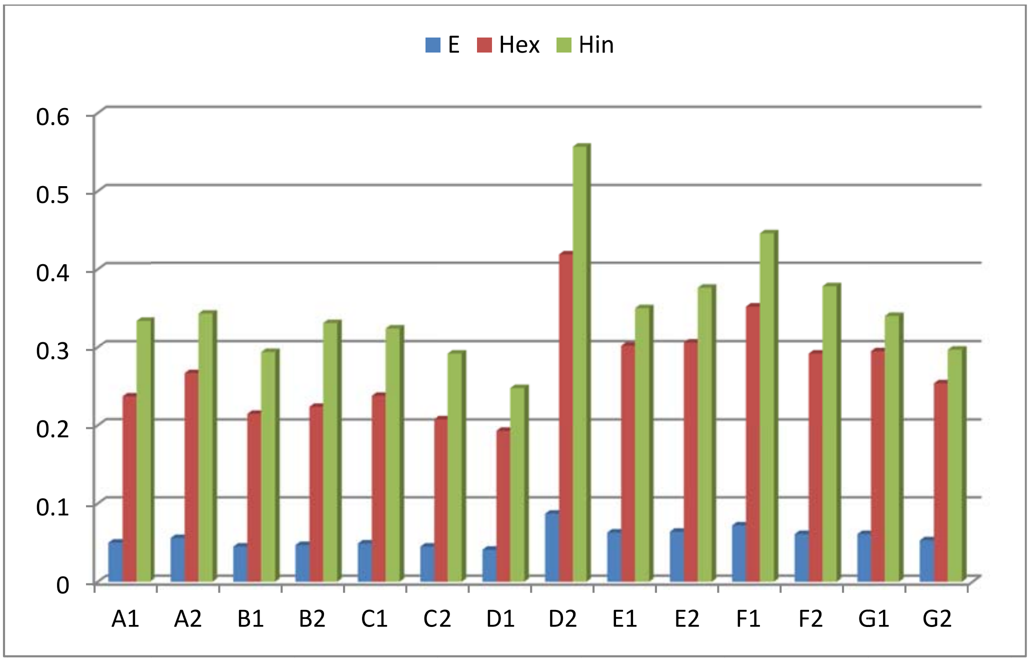

Fig. 6: Annual effective dose and the external and internal hazard.

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