Pak. J. Chem. 1(4): 155-160, 2011 Full Paper
ISSN (Print): 2220-2625
ISSN (Online): 2222-307X DOI: 10.15228/2011.v01.i04.p02

Measurements of Natural Radiation in soil of the College of Education, University of Kufa, Al-najaf Al-ashraf, Iraq

A. K. Hasan, *H. N. Majeed and S. A. Hassan
Education College of Girls, Kufa University, Al-Najaf Al-Ashraf, Iraq.
Email: alikh_hasan@yahoo.com, *heiyam_najy@yahoo.com, saad_heswa@hotmail.com

ABSTRACT
The natural radiation of soil samples in the education college for girls which is located in Kufa University in Al-Najaf Al-Ashraf govern mate have been studied. A total of 10 Soil samples were collected randomly in October 2010 then kept aside for about 4 week to ensure the equilibrium has been reached between ^{226} Ra and its decay products of short half –life and ^{228}Ra and its decay products before they were taken for gamma spectrometric analysis. The obtained values of the activity concentrations (Bq.kg^{-1}) were determined for the radionuclides ^{238}U, ^{226}Ra, ^{232}Th, ^{228} Ra, and ^{40}K. The presented results of the contents of radionuclides in soil samples showed the minimum activity concentration 4.48±0.8Bq kg^{-1} of ^{226}Ra was determined in the soil sample No. 9, while the maximum value of 49.89±10.08 Bq kg^{-1} was found in the soil from the sample No. 2. The activity concentrations of ^{232}Th were in the range 0.87±0.2 Bq kg^{-1} to 11.53±2.5 Bq kg^{-1} with a minimum value for the sample No. 1 and a maximum for the sample No. 8. The ^{40}K concentrations are disbursed as minimum value 34.54±6.7 Bq kg^{-1} in sample No.1 and maximum value 236.78±93.5 Bq kg^{-1} in sample No. 6. The highest annual effective dose rate was found to be 139.88 (μSv/y) while the world average annual effective dose equivalent is 460 (μSv/y). The corresponding gamma radiation hazard indices, annual effective dose and gamma activity concentration index (Iγr) were below those of the limit considered acceptable.

Keywords: Radioactivity Concentration, Gamma spectrometry, soil

1. INTRODUCTION:
Natural Background radiation consists of three primary types: Terrestrial Radiation Primordial, cosmogenic and a thropogenic, Primordial radionuclides are present in the earth's crust and found throughout the environment. Cosmogenic radionuclide's are produced when cosmic radiation interacts with elements present in the atmosphere and are deposited through both wet and dry deposition. Anthropogenic sources of radiation result from human activities, but are considered background because their presence is ubiquitous.[1-3]

1.1 *Terrestrial Radiation*
When the earth was formed four billion years ago, it contained many radioactive isotopes. Since then, all short lived radionuclides have decayed. Only those radionuclides with very long half lives (100 million years or more) remain, along with the radionuclides formed from the decay of the long lived radionuclides. These naturally-occurring radionuclides include isotopes of uranium and thorium and their decay products, such as radon. The presence of these radionuclides in the ground leads to both external gamma ray exposure and internal exposure from inhalation of radon.

1.2 *Soil*
Natural radioactive material in rocks and soil account for about 29 mrem or 8% of the radiation dose a person typically receives in a year from all sources (natural and manmade). The earth's crust contains small amounts of uranium, thorium, and radium as well as radioactive isotopes of several elements including potassium. The radiation dose comes from the gamma rays which are emitted from the rocks, soil, and some building materials (such as bricks and concrete)[1-7].

Uranium, radium, and thorium occur in three natural decay series, headed by uranium-238, thorium-232, and uranium-235, respectively. In nature, the radionuclides in these three series are approximately in a state of secular equilibrium, in which the activities of all radionuclides within each series are nearly equal. Two conditions are necessary for secular equilibrium. First, the parent radionuclide must have a half-life much longer than that of any other radionuclide in the series. Second, a sufficiently long period of time must have elapsed, for example ten half-lives of the decay product having the longest half-life, to allow for in growth of the decay products Under secular equilibrium, the activity of the parent radionuclide undergoes no appreciable changes during many half lives of its decay products.[5]

2. EXPERIMENTAL PROCEDURES
A total of 10 Soil samples were collected randomly in October 2010 , from the education college area which located in Al-Najaf AL-Ashraf city as shown in fig.(1), then dried at about 200 ^{0}C for 8 hour to remove any moist .The sample were crushed to fine grain size and sieved in order to homogenize it and remove big size .The powdered samples were packed in a marinelli beaker , one kilogram from each sample and sealed tightly cap kept aside for about 4 week to ensure the equilibrium has been reached between ^{226} Ra and its decay products of short half –life and ^{228}Ra and its decay products before they were taken for gamma spectrometric analysis.

*Corresponding Author Received 11th June 2011, Accepted 5th July 2011

Gamma spectrometer with scintillation detector 2"× 2" inch NaI (Tl) from SPECTRUM TECHNIQUES, INC. USA. The detector was calibrated using seven radionuclides with eight γ-ray lines emitted ranged from 122.06 to 1332.539 keV, table (1)[8-10], which has been done for calculation the efficiency calibration fig.(2) The detector was surrounded by a lead shield to reduce the background of the system.

The activity of a specific radionuclide with a gamma energy transition could be expressed using the following equation[11-13].

$$A_{Ei} = \frac{N_{Ei}}{\varepsilon_E . t . \gamma_d M} [Bq.kgm^{-1}] \ldots\ldots\ldots\ldots (1)$$

Where A_{Ei} the activity concentration of nuclide i based on energy E, N_{Ei} the net peak area for peak at energy E , ε_E the detector efficiency at energy E, t the live time , γ_d the branching ratio for energy E of this nuclide, and M the mass of the measured sample in kg.

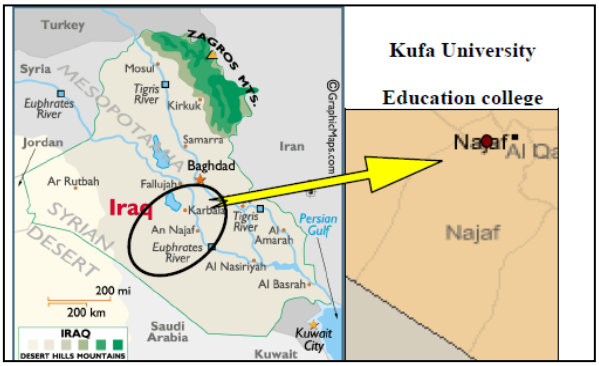

Fig-1: Map of Alnajaf Alashraf city where the education college surveyed during the present investigations

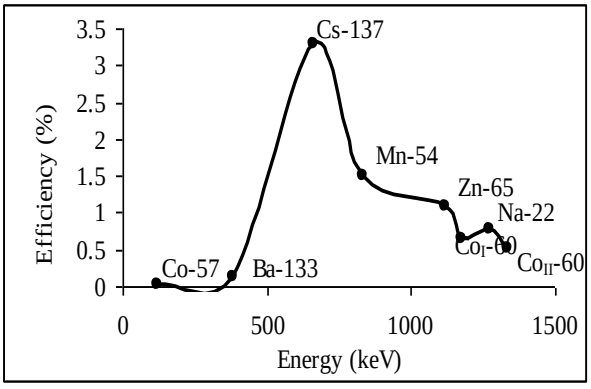

Fig-2: Full energy peak efficiency as a function of gamma ray energy for NaI (Tl) detector.

We can get the relative uncertainties of input value by[2].

$$\frac{u^2(A)}{A^2} = \frac{u^2(N)}{(N)^2} + \frac{u^2(t_c)}{(t_c^2)} + \frac{u^2 I_\gamma(E_\gamma)}{I^2{}_\gamma(E_\gamma)} + \frac{u^2\varepsilon(E_\gamma)}{\varepsilon^2(E_\gamma)} + \frac{u^2(M)}{M^2} \ldots\ldots(2)$$

Where $\frac{u^2(N)}{(N)^2}$ from spectra evaluation

Where $u^2(N)$ is called variance and $u(N)$ is the standard uncertainty, $\frac{u(t_c)}{(t_c)} \langle 10^{-6}$ neglected, $\frac{uI_\gamma(E_\gamma)}{I_\gamma(E_\gamma)}$ from table of intensity of gamma ray [9-11] , $\frac{u\varepsilon(E_\gamma)}{\varepsilon(E_\gamma)} = 2.5\%$ and $\frac{u(M)}{M} = 1-2\%$

We can use equation (2) to get the standard uncertainties for activity of soil samples or any environmental samples[2]

Table-1: Radionuclide used for efficiency calibration[8-10]

Nuclides	Energy (Kev)	γ_d	$t_{1/2}$
Na-22	1274.537	0.99940	2.6y
Mn-54	834.838	0.999746	312.3d
Co_I-60	1173.228	0.9985	5.27y
Co_{II}-60	1332.492	0.999826	5.27y
Zn-65	1115.539	0.5060	245d
Cs-137	661.657	0.8499	30.2y
Ba-133	356.0129	0.6205	10.5y
Co-57	122.06	0.8551	271.8d

The activity concentrations of the ^{232}Th and ^{238}U and their decay products ^{228}Ra and ^{226}Ra, were determined by the γ-ray transitions to measure the nuclides in the series[8-10,14] are as follows:

1. ^{234m}Pa (1001.03 keV) for ^{238}U.
2. ^{214}Bi (609.31, 1120.3 and 1764.49 keV), for ^{226}Ra.
3. ^{212}Bi (727.3 keV) for the ^{232}Th series.
4. ^{228}Ac (338.32, 463.1, 911.20 and 968.97 keV) for radium-^{228}Ra
5. ^{40}K (1460.82)keV

2.1 *Radium equivalent activity (Ra_{eq})*

Distribution of ^{226}Ra, ^{232}Th and ^{40}K in environment is not uniform, so that with respect to exposure to radiation, the radioactivity has been defined in terms of radium equivalent activity (Ra_{eq}) in Bq.kg^{-1}[6,12,13].

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \ldots.(3)$$

Where A_{Ra} , A_{Th} and A_K are specific activity concentration in Bq.kg^{-1} of ^{226}Ra, ^{232}Th and ^{40}K, respectively. The index is useful to compare the specific activity of materials containing different concentrations of ^{226}Ra, ^{232}Th and ^{40}K.

2.2 *Gamma Dose Rate (D)*

The total dose rate D in the air (out doors) due to uniform distribution of all the ^{226}Ra, ^{232}Th and ^{40}K in the beach soil 1 m above the ground surface was estimated by[6,12,13,15]

$$D = 0.427A_U + 0.662A_{Th} + 0.043A_K \ldots.(4)$$

Where D is the dose rate in (nGy.h^{-1}) and A_U , A_{Th} *and* A_K are the concentrations of uranium, thorium and potassium, respectively.

2.3 *Annual Effective Dose Equivalent (AEDE)*

In order to estimate the annual effective dose rate in air the conversion coefficient from absorbed dose in air to effective dose received by an adult had to be taken into consideration .This value is published in UNSCEAR (2000) of(0.7 Sv/Gy).The outdoor occupancy factor which is about (0.2) .

The annual effective dose equivalent was given by the following equation[6,12,13,15]

$$\text{AEDE}(\mu\text{Sv/y}) = \text{D(nGy/h} \times 8760\text{(h/y)} \times 0.2 \times 0.7\text{(Sv/Gy)} \times 10^{-3} \quad \ldots..(5)$$

2.4 *Representative level index (Iγr)*

In order to examine whether the sample meets limits of dose criteria ,Another radiation hazard index, representative level index *Iγr*, used to estimate the level of *γ*- radiation hazard associated with the radionuclides in specific investigated samples ,is defind as the following equation[6,12,13,15]

$$I_{\gamma r} = A_{Ra}/150 + A_{Th}/100 + A_K/1500 \ldots..(6)$$

The index Iγr was correlated with the annual dose due to the excess external gamma radiation caused by superficial material. Values of index I ≤1 correspond to 0.3 mSv/y, while I ≤3 correspond to 1 mSv/y. Thus, the activity concentration index should be used only as a screening tool for identifying materials which might be of concern to be used as covering material. According to this dose criterion, materials with I ≤ 3 should be avoided[15].

2.5 *External hazard index (H_{ex})*

The external hazard index (H_{ex}) was given by the following equation[6,12,13,15]

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \ldots..(7)$$

2.6 *Internal hazard index (H_{in})*

The internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index (H_{in}) is given by[6,12]

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} .....(8)$$

For the safe use of a material in the construction of dwellings, index (H_{in}) should be less than unity and the maximum value of (H_{in}) to be less than unity.

3. RESULTS AND DISCUSSION

Soil is a significant part of the human environment that provides resources for food production. It is a very dynamic ecosystem of particular importance since, once contaminate, the soil acts as a potentially long-term source of environmental contamination of food, water and air[16].

Table-2: Concentrations of radionuclide for each sample

Sample No.	^{238}U	^{226}Ra	^{232}Th	^{228}Ra	^{40}K
1	41.45±7.9	37.85±3.7	0.87±0.2	0.82±0.2	34.54±6.7
2	32.04±9.6	49.89±11.1	1.28±0.4	0.75±0.2	62.63±12.6
3	33.28±9.4	43.45±9.9	1.16±0.3	1.1±0.3	38.83±9.9
4	77.17±15.6	49.25±7.1	3.06±0.6	1.02±0.3	114.77±22.5
5	42.64±12.8	35.56±7.9	1.71±0.5	1.006±0.3	127.94±23.2
6	112.47±37.8	6.41±1.7	2.09±0.4	3.54±1.2	236.78±93.5
7	123.98±33.9	15.91±4.8	6.35±1.5	9.506±1.5	49.59±38.7
8	153.5±49.6	23.32±15.3	11.53±2.5	9.5±2	76.75±72.1
9	253.63±43.5	4.48±0.8	3.66±1.3	1.86±0.3	77.64±48.9
10	83.46±33.7	26.52±5.3	7.13±1.7	11.33±1.7	133.54±67.1
Aver.	95.36±25.4	29.27±6.8	3.88±0.9	4.04±0.8	95.305±39.5
Max.	253.63±49.6	49.89±15.3	11.53±2.5	11.33±2	236.78±93.5
Min.	32.04±7.9	4.48±0.8	0.87±0.2	0.75±0.2	34.54±6.7

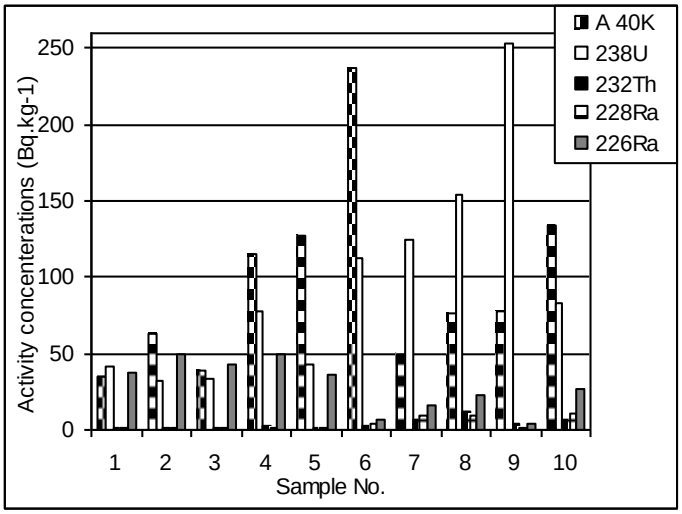

Fig-3: The specific activity of ^{238}U, ^{232}Th, ^{226}Ra, ^{228}Ra and ^{40}K in Bq. kg^{-1}

The obtained values of the activity concentrations (Bq.kg^{-1}) determined for the radionuclides ^{238}U, ^{226}Ra, ^{232}Th , ^{228}Ra , and ^{40}K, in the analyzed soil samples were listed in Table (2) fig.(3) , while the ^{238}U/^{226}Ra , ^{232}Th/^{228}Ra and ^{238}U/^{232}Th ratio were shown in fig (4). The presented results of the contents of radionuclides in soil samples showed. The minimum activity concentration 4.48±0.8Bq kg^{-1} of ^{226}Ra was determined in the soil sample No. 9, while the maximum value of 49.89±10.08 Bq kg–1 was found in the soil from the sample No. 2. The activity concentrations of ^{232}Th were in the range 0.87±0.2 Bq kg^{-1} to 11.53±2.5 Bq kg^{-1} with a minimum value for the sample 1 and a maximum for the sample No. 8. The ^{40}K concentrations are disbursed as minimum value 34.54±6.7 Bq kg^{-1} in sample No. 1 and maximum value 236.78±93.5 Bq kg^{-1} in sample No. 6. The ^{238}U/^{232}Th ratio showed the low concentration of ^{232}Th series with respect to ^{238}U series .The differences were attributable to the geochemical composition and origin of soil types in this area.

All calculated Iγr, external and internal hazard indexes were below the unity. Therefore, the obtained values from this preliminary study were all lower than the accepted, average worldwide value. The highest annual effective dose rate was found to be 139.88 (μSv/y) were less than the world average 460 (μSv/y)[6,12,13,15].

Table-3: Radium equivalent (Bq/kg), dose rate (nGy/h) and *AEDE (μSv/y),* for all samples

Sample No.	Ra_{eq}	D(nGy/h)	AEDE(μSv/y)
1	41.76	19.76	24.23
2	56.56	17.23	21.13
3	48.11	16.65	20.42
4	62.47	39.91	48.95
5	47.86	24.84	30.47
6	27.64	59.59	73.08
7	28.83	59.28	72.706
8	45.73	76.48	93.8
9	15.69	114.06	139.88
10	47.01	46.106	56.54
Ave.	42.17	47.39	58.12
Max.	62.47	114.06	139.88
Min.	15.69	16.65	20.42

Table-4::The external, internal ,and representative hazard indexes for all samples

Sample No.	$H_{ex}\leq 1$	$H_{in}\leq 1$	Iγr≤1
1	0.12	0.23	0.03
2	0.17	0.32	0.059
3	0.14	0.27	0.044
4	0.20	0.37	0.1139
5	0.162	0.29	0.109
6	0.13	0.2	0.202
7	0.112	0.19	0.16
8	0.18	0.307	0.229
9	0.072	0.115	0.1
10	0.182	0.309	0.23
Ave.	0.148	0.262	0.129
Max.	0.2	0.373	0.23
Min.	0.072	0.115	0.037

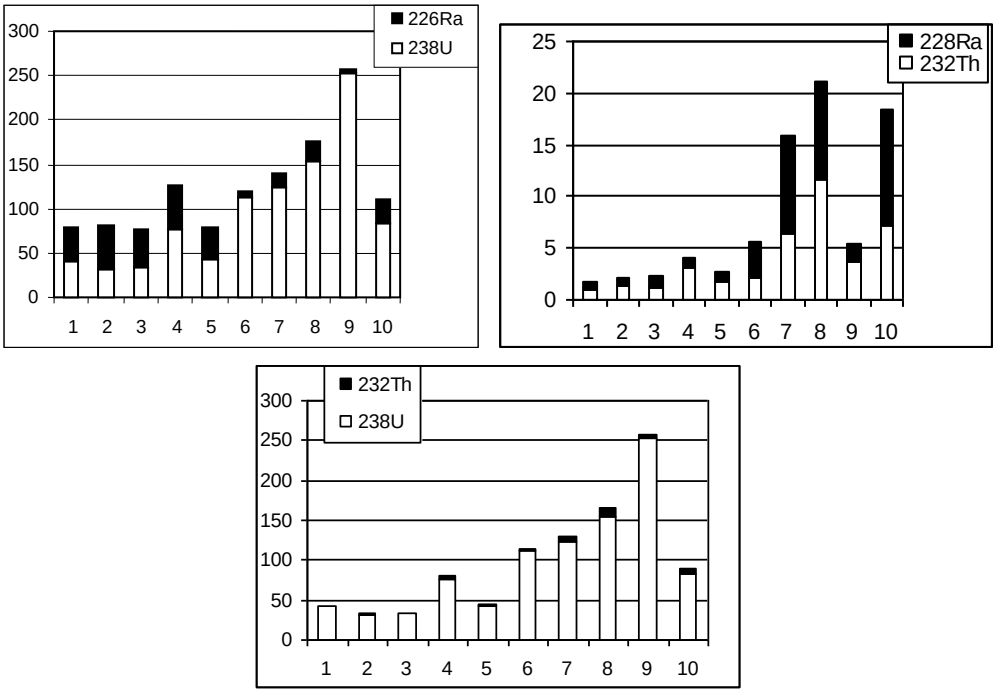

Fig-4: $^{238}U/^{226}Ra$, $^{232}Th/^{228}Ra$ and $^{238}U/^{232}Th$ ratio respectively .

4. CONCLUSION

The measured levels of the natural radiation background in the present study from the all investigated samples showed that the studied areas have normal levels of background radiation[9-11]. The corresponding gamma radiation hazard indices, annual effective dose and gamma activity concentration index (Iγr) were below the acceptable limits.

5. REFERENCES

1. Okeyode, I., Oluseye, A., Physics International **(2010)** 6: 1-8, http://dx.doi.org/10.3844/pisp.2010.1.8.
2. Harb, S., PhD thesis, ZSR, Hannover University, Germany **(2004)**.
3. Damon, R MSc. thesis, the University of the Western Cape, Bellville, **(2005)**.
4. Argonne National Laboratory, Natural Decay Series: Uranium, Radium, and Thorium EVS Human Health Fact Sheet, **(2005)**.
5. Argonne National Laboratory, Potassium-40, EVS Human Health Fact Sheet, **(2005)**.
6. Radenković, S., Alshikh, V., Andric, V., and Miljanic S., J. Serb. Chem. Soc. **(2009)** 74: 461–470.
7. Egunyinka, O., Olowookere, C., Jibirind, N., Babalola, I., and Obed, R., The Pacific Journal of Science and Technology, **(2009)** 10: 742-752.
8. International atomic energy agency, Update of x ray and gamma ray decay data standards for detector calibration and other applications, Volume 1, Vienna **(2007)**.
9. International atomic energy agency, Update of x ray and gamma ray decay data standards for detector calibration and other applications, Volume 2, Vienna **(2007)**.
10. IAEA, “Guidelines for radioelement mapping using gamma ray spectrometry data", Vienna **(2003)**.
11. Ebaid, Y., Rom. Journ. Phys. **(2010)** 55-69-74.
12. Harb, S., El-Kamel, A., Abd El-Mageed, A., and Wafaa, R., Proceedings of the 3rd Environmental Physics Conference, Feb. Aswan, Egypt, **(2008)** 19-23.
13. Al-Sulaiti, H., Regan, P., Bradley, D., Matthews, M., Santawamaitre, T., and Malain, D., IX Radiation. Physics & Protection onference, November Nasr City, Cairo, Egypt. **(2008)** 15-19.
14. Abdulla, A., Aldrgazelli, S., and Elias, M., “Experimental Nuclear Physics”, Iraq, **(1990)**.
15. Al-Saleh, F., and Al-Berzan, B., Journal of Nuclear and Radiation Physics **(2007)** 2, 25-36.
16. Al-Saif, A., MSc. Thesis King Saud University, **(2009)**.