Determination of Natural Radioactivity in Soil Samples from Different Locations in Al-Qadisiyah Governorate

Abbas A. Sweaf
We'am S. Malik

Department of Physics, College of Education, University of Al-Qadisiya, Al-Diwaniyah, IRAQ

In the present work, the radioactivity of four soil specimens has been measured, which were collected from various sites from Al-Qadisiyah Governorate. The qualitative activity of natural radionuclides ^{238}U, ^{232}Th and ^{40}K for soil specimens were evaluated by utilizing gamma-ray spectroscopy with NaI(Tl) detector of 3"×3" dimensions. The results revealed that the qualitative activity for ^{238}U was varied from 9.290 to 22.980 Bq/kg, for ^{232}Th was varied from 4.550 to 7.880 Bq/kg, for ^{40}K was varied from 95.328 to 336.550 Bq/kg, with an average values of 15.945±2.98, 5.925±3.93, and 190.720±22.20 Bq/kg, respectively. To survey the radiological peril in soil, radium effective activity, absorbed gamma dose in air, annual effective dose equivalent (inner and outer), gamma concentration level index and both interior and exterior radiation peril index have been computed, and all the existed results were less than recommended by the International Committee for the Radiation Protection (ICRP).

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1. Introduction

The sources of radiation to which human beings are exposed permanently are either natural, of cosmic or industrial origin, which human involves in its manufacture for various purposes. Almost all the materials encompassing us contain a small proportion of radioactive material, consequently human are being exposed to a low level of radiation background, so radiation has an effect on environmental contamination and its effect may remain for a long time [1,2]. Radioactive contamination is one of the most important problems facing countries of the civilized world, because of the damage it causes to the environment, to various living things and to the health of humans. The source and behavior of the radioactive pollutants newly deposited in the soil is different from those of the radionuclides originally present in the formed soil, as these pollutants are absorbed by plants. Therefore, researchers are interested in assessing the concentration of environmental elements from soil, water, air and food [3,4]. The soil represents the surface layer of the earth and consists of 45% metal materials, 5% organic materials, represented by accumulations of plant and animal wastes, 25% gas-like air (CO_2, N_2, O_2 and others), 25% water, contamination in the soil, in general, occurs when chemical elements are added or lost. Thus, soil fertility and formative depend on the natural, chemical and, biological composition of these components, which directly or indirectly effect those who live above their surface from various creatures [5,6], In addition to the deliberation of radioactive materials and their application in many fields of the most important threats to the elements of the environment, including the soil. Thus, it causes humans to exhibit radiation, so it is essential to know the nature of these materials and their dangers and how to protect against them and utilized them safely [7]. The study of the interaction of radiation with these material is necessary to know the high levels of radioactive elements such as uranium, thorium, potassium and measurement of the radiation doses represented by gamma rays, which are one of the most common and widespread radiations that lead to disturbance of the vital balance of human and his environment if exposed to them [2,3]. The human body contains some radionuclides, the most important of which are uranium, thorium and potassium in varying proportions, many recent studies and research have shown that nuclear radiation has serious biological effects on the life of living organisms, especially when soil and thus these organisms are exposed to greater doses than acceptable values annually [8,9]. Considering the elements of the environment are affected by radioactivity firstly, the study area was exposed to bombing and environmental neglect more than the rest of the regions secondly, and there are extremely few radiological environmental studies in this field. Therefore, it is necessary to assess the radioactive quantity of radionuclide ^{238}U, ^{232}Th, ^{40}K in soil specimen were gathered from the Al-Qadisiyah governorate and to find appropriate solutions to reduce soil contamination, as well as to estimate the radiological perils as a result of the rising population density of the area studied and use the land in agriculture, which may have an effect on the population of the area and comparison the results with the values recorded globally [10].

The specific activity (A) can be calculates of each radionuclide by the following equation

$$A = \left(\frac{N_{net}}{\varepsilon . I_{\gamma} . M . t}\right) \pm \left(\frac{\sqrt{N_{net}}}{\varepsilon . I_{\gamma} . M . t}\right) \quad \left(\frac{\text{Bq}}{\text{kg}}\right) \qquad (1)$$

where N_{net} represents the net count expressed in (c/s)

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(area under peak of specified energy after background subtraction), ε represents detector efficiency, t represents time (expressed in s) for spectrum collected, I_γ and M are the transition probability of emitted gamma-ray and weight of the sample (expressed in kg), respectively [11]

The activities due to ^{238}U, ^{232}Th and ^{40}K can be represented from a single quantity that called radium equivalent lapelled as (Ra_{eq}) in Bq/kg. It represents a weighed sum for activities of the three nuclides of the natural radio and is relying on the assumption that 370, 259, and 4810 Bq/kg of ^{238}U, ^{232}Th, and ^{40}K, respectively, produce same gamma-radiation dosage rate. The activity of the radium equivalent (Ra_{eq}) has been estimated using the following relation [12]

$$R_a = A_U + 1.43A_{Th} + 0.677A_K \quad (2)$$

A_U, A_{Th} and A_K represent the specific activity of ^{238}U, ^{232}Th and ^{40}K, respectively, expressed in Bq/kg

Radon (^{222}Rn) is hazardous to respiratory organs as well. Internal and external exposure to the radon (^{222}Rn) are quantified by internal hazard index H_{in}, which can be defined by the relations [13]

$$H_{in} = \frac{A^{238}\mathrm{U}}{185} + \frac{A^{232}\mathrm{Th}}{259} + \frac{A^{40}\mathrm{K}}{4810} \quad (3)$$

$$H_{ex} = \frac{A^{238}\mathrm{U}}{370} + \frac{A^{232}\mathrm{Th}}{259} + \frac{A^{40}\mathrm{K}}{4810} \quad (4)$$

where H_{ex} represents the external hazard index

Maximum values of the H_{in} should be lower than unity and H_{ex} values to be also lower than unity corresponds to the upper Ra_{eq} activity limit (370 Bq/kg) to keep the hazard of radiation insignificant. Evaluation the annual effective dose (AED) can be estimated by taken within consideration [14,15]

(a) conversion coefficient of absorbed dosage in air to effective dosage

(b) indoor occupancy factor

By use dosage rate data which is obtained by the values of concentration for the radio nuclides in the soils, adopting factor of 0.7 mSv/y [6] from rate of absorbed dosage in the air to effective dosage that is received by the adults and taking under consideration that the people, in general, spend 20% of their time outdoors, and annual effective dosages are estimated outdoor annual effective dosage [9]:

$$\left(\frac{mSv}{y}\right) \times 8760h \times \frac{0.7Sv}{G} \times 0.20 \times 10^{-6} = ADE\left(\frac{nGy}{h}\right) \quad (5)$$

Indoor annual effective dosage is

$$\left(\frac{mSv}{y}\right) \times 8760h \times \frac{0.7Sv}{G} \times 0.8 \times 10^{-6} = ADE\left(\frac{nGy}{h}\right) \quad (6)$$

$$AED = 0.462A_{\mathrm{U}} + 0.621A_{\mathrm{Th}} + 0.417A_{\mathrm{K}} \quad (7)$$

The aim of study was to assess the activity of naturally occurring radioactivity elements in the collected soil samples, those has found to have normal concentrations of elements ^{238}U, ^{232}Th and ^{40}K, and no anomalies existing. The reason for low levels of radioactivity in the regions under study may be accounted to climatic and geographical conditions. The decrease or increase of the recorded values is due to several factors such as soil type, the geological nature of the area, the region selected (agricultural or industrial) or may be exposed to other external factors.

2. Experimental Work

Then soil specimens were collected from various sites in Al-Qadisiyah governorate. Impurities were removed from the soli specimens and then these specimens were crushed and grinded until they became in the form of a fine powder. Specimens were left to expose to sunlight for 7 days to be dry and moisture-free and then sieved with a 1 mm mesh size sieve to obtain a homogeneous soil free of impurities. The specimens were weighed using a sensitive balance, then the specimen were placed in a liter Marinelli cups and left for 4 weeks to obtain radioactive balance between the radionuclides. The normal radioactivity of radionuclides (gamma-rays) were measured depending on the high penetrating strength of gamma-rays in the specimens by utilizing the electronic count and analysis technique to detect ionizing radiation from the sodium iodide system, which contains of a scintillation sensor sodium iodide stimulate by thallium NaI(Tl) with a multichannel analyzer reaching to about 2048 channel connected with analog to digital signals conversion unit which assists the analyzer in converting the pulses into numerical values. Both the detector and the holder are placed inside a shield to reduce the radiative background recorded by the detector.

Calibration can be defined as the linear relationship between the detector out pulse and energy gamma which falling on the crystallized capacity. Standard sources of known energies and intensity may be used for calibration of emitter gamma spectrum. Many standard sources such as ^{60}Co, ^{22}Na, and ^{137}Cs were used in order to obtain energies in the present study as shown in Fig. (1).

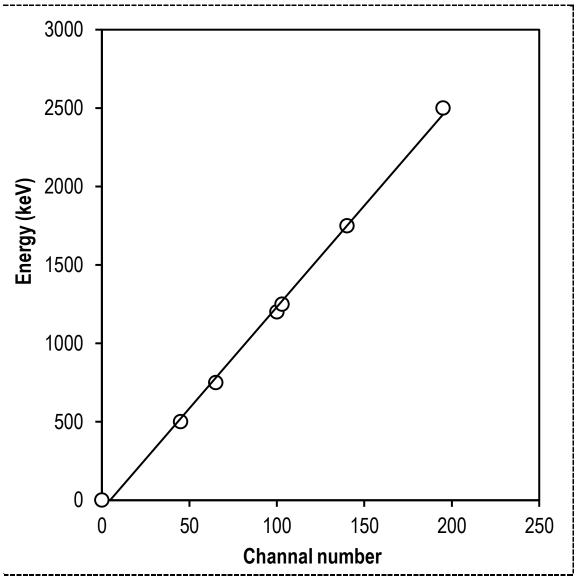

Fig. (1) The relationship between the channel number and energy gamma rays

Detector efficiency represents the ratio between the number of the photons gamma that fallen on it the number of pulses emerging from detector. It can be given by the following equation:

$$\varepsilon = \left[\frac{N}{A.I_{\gamma}.t}\right] \times 100\% \qquad (8)$$

In order to calibrate the detector efficiency, the known energies of record sources was used, as well as the decay equation to measure the final specific activity radioactive sources were also radioactivity recorded by the detector for each energy from the energies of radioactive sources to measure for a period of 3600 s then the efficiency was measured. Figure (2) shows the relationship between efficiency and energy the standard sources used.

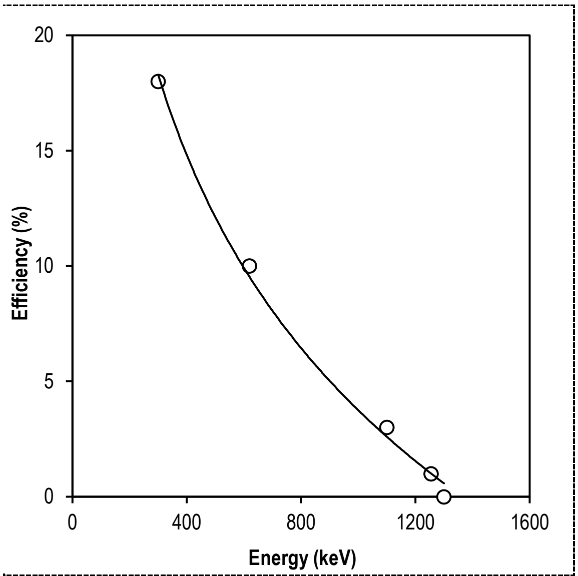

Fig. (2) The relationship between efficiency and energy the standard sources used

In this study, the natural radiation of soil samples was studied at a temperature of 60 °C for 72 hours. Each sample was filled and tightened in a PVC compartment and spared for about a month and half period to allow the radioactive balance between the daughter products of radon (^{222}Rn), thoron (^{220}Rn) and their shorter-lived decay products be allowed. A 0.5 kg of soil was used per sample. These samples are taken from an approximately 10 cm depth. They were estimated by using gamma spectrometer with scintillation detector NaI(Tl) from SPECTRUM TECHNIQUES INC.USA. The sample is put vis-à-vis over the detector for 5 hours, the contribution of the radiological background was subtracted from the peak area of the measured sample [6] because of the accuracy of NaI(TI) reagent in detecting vanishing gamma energies that did not separate the peak well. Hence, the estimation of the activity focuses is accessible at high energies as that secure in our outcomes from gamma beam emitted the series of ^{238}U (the gamma line 1765 keV for ^{214}Bi) and ^{232}Th (the gamma line 2614 keV for which are equilibrium together with them), however, ^{40}K was assessed directly by 208 means of its gamma line of 1460 keV [7,8].

3. Results and Discussion

Four soil specimens were collected from various sites in the Al-Qadisiyah governorate, and the qualitative activity of natural radionuclides (^{238}U, ^{232}Th and ^{40}K) was calculated using the gamma rays spectroscopy with NaI(Tl) detector, as the radiological peril evidence of the soil specimens were calculated as in table (1). From the results in this table we conclude that the lowest value of qualitative activity (^{238}U, ^{232}Th and ^{40}K) in soil specimens was equal to 9.920, 4.550 and 95.328 Bq/kg, respectively, and the highest value for ^{238}U, ^{232}Th and ^{40}K was equal to 22.980, 7.880 and 336.616 Bq/kg, respectively, as in Fig. (3).

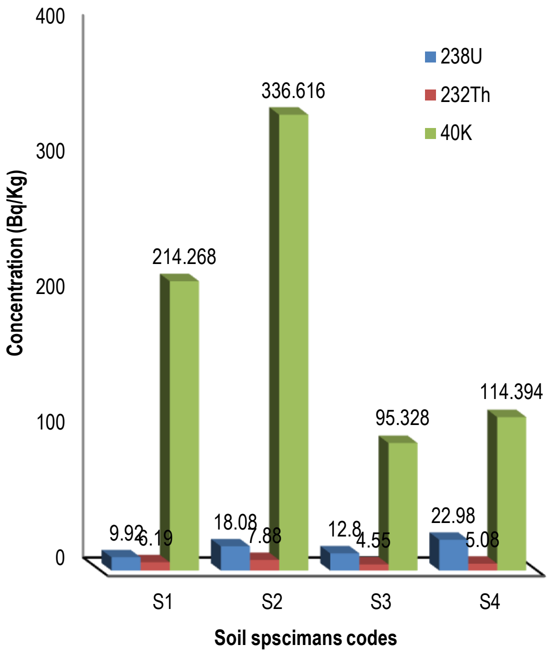

Fig. (3) Concentrations of the ^{238}U, ^{238}Th and ^{40}K for samples

The natural radioactivity for gamma-ray due to long-lived gamma emitters in 4 samples were analyzed. The results of arithmetic mean specific activity values ± standard error (S.E.) in Bq/kg for ^{238}U, ^{232}Th and ^{40}K in these samples were compared to the worldwide median values reported by UNSCEAR (2000) as given in table (1). This table shows that the highest value of specific activity for ^{238}U was 22.98±0.52 Bq/kg in sample S4, while the lowest value of specific activity in sample S1 was 9.92±0.42 Bq/kg, with an average of 15.945±0.45 Bq/kg. Also, the same table shows that the highest value of specific activity for ^{232}Th was 7.88±1.12 Bq/kg in sample S2, but the lowest specific activity was 4.55±0.42 Bq/kg in sample S3 with an average of 5.925±0.71 Bq/kg. The highest specific activity corresponding to radionuclide ^{40}K was 336.61±0.52 Bq/kg in sample S2, while the lowest value was 95.32±0.23 Bq/kg in sample S3, with an average of 190.15±0.51 Bq/kg, as shown in Fig. (3). We can conclude that the lowest value of qualitative activity

(^{238}U, ^{232}Th and ^{40}K) in soil specimens was equal to 9.920, 4.550 and 95.328 Bq/kg, respectively, the highest value for ^{238}U, ^{232}Th and ^{40}K was 22.980, 7.880 and 336.616 Bq/kg, respectively, as shown in Fig. (3).

In table (2), the lowest value of qualitative activity (^{238}U, ^{232}Th and ^{40}K) in soil specimens was 9.920, 4.550 and 95.328 Bq/kg, respectively, the highest value for ^{238}U, ^{232}Th and ^{40}K was 22.980, 7.880 and 336.616 Bq/kg, respectively. There is a contrast between the lowest and highest value of the measured sites and this variation is due to the geological nature of the inspected area and the different terrain, selected area (residential, agricultural or industrial) soil type, the chemical fertilize utilized for agricultural purposes.

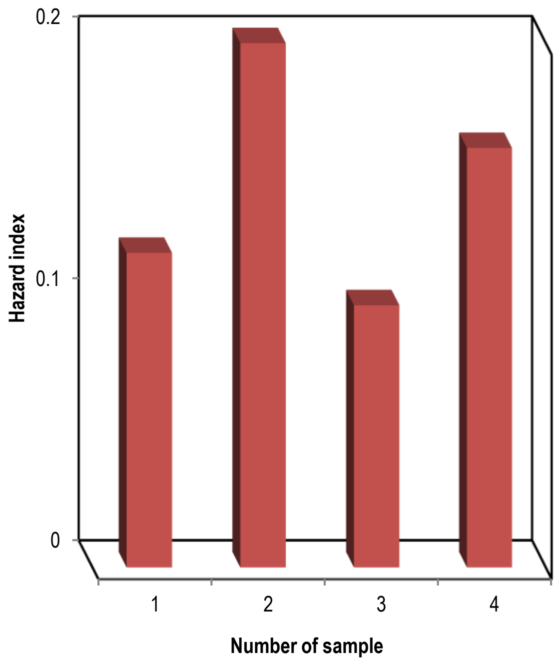

Fig. (4) The relationship between number of sample and hazard index

The lowest values of the radium effective activity (Ra_{id}) and absorbed gamma dose in air in soil specimens were equal to 26.66±2.04 Bq/kg and 12.72±0.95 nGy/h, respectively, the highest values of Ra_{id} and $D\gamma$ were equal to 82.918 Bq/kg and 38.082 nGy/h, respectively, as shown in Fig. (4), and the general rates of Ra_{id} and $D\gamma$ were equal to 58.14±4.52Bq/kg and 28.53±2.05 nGy/h, respectively. Current results show that the rates of Ra_{id} and $D\gamma$ in soil specimens were less than the values of the permitted Global Rate equal to 370 Bq/kg and 55 nGy/h, respectively [13]. In Fig. (3), it can be noted that the relation between number of sample and hazard index values lying in the range of 0.1±1.026; S3 to 0.2±1.344; S2. It was lower than limit according to the radiation protection standards [16].

5. Conclusions

It was found that normal concentrations of elements ^{238}U, ^{232}Th and ^{40}K are measured in soil samples collected from various sites in Al-Qadisiya governorate and no anomalies exists. The reason for low levels of radioactivity in these samples may be accounted to climatic and geographical conditions. The decrease or increase of the recorded values is due to several factors such as soil type, the geological nature of the area, the region selected (agricultural or industrial) or may be exposed to other external factors. We can say that the current study results of the radioactive quantity of radionuclide (^{238}U, ^{232}Th, and ^{40}K) and radiological peril evidence of Ra_{id}, $D\gamma$, I_{γ}, and H_{in}, and H_{ex} of the soil specimens were less than recommended by the International Committee for the Radiation Protection [13], and therefore do not pose a significant peril to human health and environment in terms of radiological and when utilized for agriculture or other purposes.

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Table (1) Activity Concentration of ^{232}Th, ^{238}U and ^{40}K (Bq/kg) in soil samples investigated in this study

No	Sample code	Specific activity (Bq/kg)		
		^{238}U	^{232}Th	^{40}K
1	S1	9.92±0.42	6.19±0.18	214.26±0.89
2	S2	18.08±0.11	7.88±1.12	336.61±0.52
3	S3	12.8±0.96	4.55±0.42	95.32±0.23
4	S4	22.98±0.52	5.08±0.14	114.39±0.53
	Average ± S.E	15.945±0.45	±0.71 5.925	190.15±0.51

Table (2) The equivalent radiation and annual absorbed dose to the studied of the samples

Sample	Location	Effective Dose Rate (mSv/y)	Absorbed Dose Rate (nGy/h)	Radium Equivalent (Bq/kg)	Activity Concentration Index
S1	Department of Physics, College of Education	0.085±0.005	17.36±2.11	35.277±2.11	0.27
S2	College of Art	0.140±0.010	28.53±2.05	58.14±4.52	0.44
S3	College of Culture	0.062±0.005	12.72±0.95	26.66±2.04	0.19
S4	College of Engineering	0.091±0.006	18.54±1.17	39.05±2.52	0.28