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Natural Radioactivity in Soil Samples in Nineveh Province and the Associated Radiation Hazards

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Abstract The natural radioactivity due to presence of ^{226}Ra, ^{232}Th and ^{40}K in soil of Nineveh zone, Nineveh province, Iraq were measured by using gamma-ray spectrometry based on high-purity germanium detector. The specific activity of soil samples ranged from 16.21 to 38.83 Bq/kg with an average of value of 32.52±6.48 Bq/kg, 8.53 to 28.37 Bq/kg with an average of 20.30±5.36 Bq/kg, 236.03 to 613.11 Bq/kg with an average of 378.93± 123.29Bq/kg, and 2.18 to 17.92 Bq/kg with an average of 8.17± 5.55 Bq/kg for ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs respectively. The study also examine some radiation hazard indices such as Radium equivalent activity (R_{aeq}), Absorbed gamma dose rate (D), External hazard index (H_{ex}), Internal hazard index (H_{in}) and gamma index (I_{γ}). These calculated hazard indices to estimate the potential radiological health risk in soil. The radium equivalent activity average (R_{aeq}) was less than the permitted value (370 Bq/kg). The average absorbed dose rate value also less than the permissible limit of 55 nGy/h. The external hazard index, internal hazard index and gamma index of soil samples were less than unity.

Keywords: *soil radioactivity, high-purity germanium detector, absorbed dose rate, activity concentrations, external hazard index*

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1. Introduction

Radiation is present everywhere and man is knowingly or unknowingly being continuously exposed to radiations present in environment (natural). The natural radiations surrounding the life on earth can either be terrestrial or extraterrestrial (cosmic) origin. The ionizing radiations a, b and c emitted from various terrestrial materials (soil, rocks, and etc.) coming from naturally occurring radionuclides such as uranium, thorium etc., their isotopes, their decay products and some singly occurring radionuclides such as ^{40}K, ^{87}Rb contribute to the terrestrial radiations [1]. Natural radioactivity can be found, in low concentrations, throughout the geology of the planet. It is naturally occurring in many rocks, soils, and waterways. Phosphate rocks are one of the matrices that contain higher levels of natural radioactivity than the background. As the world population continues to grow, so does the world’s need for food. The increased demands of food production have led to a steady increase in the use of phosphate fertilizers [2,3]. Natural radioactivity exists widely in the terrestrial environment. There are many sources of radiation and radioactivity in the environment.

Gamma radiation emitted from naturally occurring radionuclides, also called terrestrial background radiation, represent the main external source of irradiation of the human body. It is located in different geological formations such as the surface of the earth, rocks, water, plants and even the air. The concentration of the natural radioactive materials depends on situation of geology and geography and appears at different level in soils of each different geological region [4,5].

The exposure of human beings to ionizing radiation from natural sources is a continuing and inescapable feature of life on earth. For most individuals, this exposure exceeds that from all man-made sources combined. External exposures outdoors arise from terrestrial radionuclides present at trace levels in all soils. The specific levels are related to the types of rock from which the soils originate. Natural environmental radioactivity and the associated external exposure due to gamma radiation conditions, and appear at different levels in the soils which the soils originate [4,6]. The applications of radiations have become part and parcel in human life. We receive radiation emitted from the floor and walls of our homes, food we eat and drink and the air we breadth. The concept of technologically enhanced natural radioactivity (TENORM) was introduced in the mid-seventies. It represents the unintentional exposure to natural sources of radiation which would not exist without the technological activity. The natural radioactivity in the environment is the main source of radiation exposure for human body. Natural radionuclide in coal, soil and water contribute a significant amount of background radiation exposure to the population through inhalation and ingestion as well as through direct external exposure [4,7].

Natural radioactivity is widespread in the earth environment and it exists in various geological formations such as earth crust, rocks, soils, plants, water and air. Terrestrial radioactivity and the associated external exposure due to gamma radiation, depends primarily on the geological formation and soil type of the location; and these factors (geology and soil type) greatly influence the dose distribution from natural terrestrial radiation [4,8]. Radiation is present everywhere and man is knowingly or unknowingly being continuously exposed to radiations present in environment (natural). The natural radiations surrounding the life on earth can either be terrestrial or extraterrestrial (cosmic) origin. The ionizing radiations a, b and c emitted from various terrestrial materials (soil, rock, sand etc.) coming from naturally occurring radionuclides such as uranium, thorium etc., their isotopes, their decay products and some singly occurring radionuclides such as 40K, 87Rb contribute to the terrestrial radiations [9]. Since the creation of our earth soil and sediment contain different radionuclides. At the present age of our earth, these terrestrial radionuclides are mainly members of the two natural radioactive series, namely uranium (^{238}U) and thorium (^{232}Th) series, and the isotope potassium (^{40}K).These natural radionuclides cause radiation exposure to us externally through gamma ray emission and internally as well, through inhalation and food chain [10,11]. The aim of the present work is determine the specific activity concentrations of 226Ra, 232Th, 40K and 137Cs, radium equivalent activity, absorbed gamma dose rate, external and internal hazard indices and gamma index in surface soil samples in some selected districts in Nineveh province by using high purity germanium (HPGe) detector.

2. Materials and Methods

2.1. Study Area

This study was carried out at Nineveh province, ten districts has been selected from the center of Mosul city(i.e. Al-Medan, Camp of Gazlany and college of Agriculture in Univ. of Mosul) and others from some small towns outside the center of Mosul city like(Sinjar, Rabeaa, Telfar, Al-Koosh, Telkaif, Al-Hamdanea and Bacheeka) as shown in Table 1.

Table 1. Names and codes of collected soil samples from Nineveh province.

Sample no.	Sample code	Sample name
1	S1	Sinjar
2	S2	Rabeaa
3	S3	Telfar
4	S4	Al-Koosh
5	S5	Telkaif
6	S6	Al-Hamdanea
7	S7	Bacheeka
8	S8	Camp of Gazlany
9	S9	Al-Medan
10	S10	College of Agriculture

2.2. Collection and Preparation of Samples

A total of ten soil samples have been collected from ten districts of Nineveh area. These samples were crushed and dried in an oven at110 C° for 24 h to ensure than any significant moisture was removed from the samples. Later, they were grinded into fine powder to pass through a 2mm mesh and the homogenized sample was sealed in marinelli beaker. The samples were then stored and kept sealed for about a four- week period to allow radioactive equilibrium among the daughter products of radon (^{222}Ra), thoron (^{220}Ra) and their short lived decay products.

2.3. Gamma Ray Spectrometry

Each Sample was measured with gamma –ray spectrometry consisting of vertical HPGe setup and multichannel analyzer (8192) channel, with the following specifications: resolution (FEHM) at 1.33 MeV ^{60}Co is 2.0 keV, relative efficiency at 1.33 MeV ^{60}Co is 40%. The detector shield are with activity adequate to accommodate large samples. Shield has walls 10 cm lead, thick lined inside with graded absorber of Cd ~ 1.6 mm, Cu~ 0.4mm. This shield serves to reduce different background radioactivity. To minimize the effect of the scattered radiation from the shield, the detector is located in the center of the chamber. Then the sample was placed over the detector for at least 2h. The spectrum was evaluated with the computer software program Maestro(EG&G ORTEC). The energy regions selected for the corresponding radionuclides were 609 keV, 11120 keV for ^{214}Bi for ^{226}Ra, 911keV and 969 keV of ^{228}Ac for ^{232}Th and 1460 keV for ^{40}K.

The activity concentration of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs were calculated using the following relation [12]:

$$A = (CPS)net / I .\varepsilon.m.t \qquad (1)$$

Where A is the activity concentration in Bq/kg (CPS) net is the (count per second) and equal [(CPS) sample –(CPS) background], I is the intensity of γ-line in a radionuclide, ε is the measured efficiency of each γ- line observed, m is the weight of each sample and t is the sample counting time 7200 sec.

3. Results and Discussion

3.1. Activity Concentration in Soil Samples

From Table 2, it can be noticed that the highest value of specific activity concentration of ^{226}Ra was found in (S1)(Sinjar) district which was equal to (38.83 Bq/kg), while the lowest value of specific activity concentration of ^{226}Ra was found in (S9) (Al-Medan) district which was equal to (16.21 Bq/kg), with an average value of (32.52± 6.48 Bq/kg).The present results have shown that values of specific activity concentrations in the studied districts in Nineveh province were lower than value of specific activity concentration of ^{226}Ra global limit which equal to (370 Bq/kg) [4]. The highest value of specific activity concentration of ^{232}Th was found in (S2)(Rabeaa) district which was equal to (28.37 Bq/kg), while the lowest value of specific activity concentration of ^{232}Th was found in (S9) (Al-Medan) district which was equal to (8.53 Bq/kg), with an average value of (20.30± 5.3 Bq/kg).The present results have shown that values of specific activity concentrations in the studied districts in Nineveh province were lower than value of specific activity concentration of ^{232}Th global limit which equal to (45 Bq/kg) [4]. The highest value of specific activity concentration of ^{40}K was found in (S2)(Rabeaa) district which was equal to (613.11 Bq/kg), while the lowest value of specific activity concentration of ^{40}K was found in (S10) (College of Agriculture) district which was equal to (261.81 Bq/kg), with an average value of (378.93± 123.29 Bq/kg).The present results have shown that values of specific activity concentrations in the studied districts in Nineveh province were lower than value of specific activity concentration of ^{40}K global limit which equal to (420 Bq/kg) [4] except Rabeaa and Camp of Gazlany districts (S2 and S8). The highest value of specific activity concentration of ^{137}Cs was found in (S8)(Camp of Gazlany) district which was equal to (17.92 Bq/kg), while the lowest value of specific activity concentration of ^{137}Cs found in (S5) (Telkaif) district which was equal to (2.18 Bq/kg), with an average value of (8.17± 5.55 Bq/kg).The present results have shown that values of specific activity concentrations in the studied districts in Nineveh province were lower than value of specific activity concentration of ^{137}Cs global limit which equal to (14.8 Bq/kg) [4] except Al-Hamdanea and Backeeka districts (S6 and S7).The results of the activity concentrations for ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs were shown graphically in Figure 1, Figure 2, Figure 3 and Figure 4.

Table 2. Specific activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs for soil samples in Nineveh province.

Samples Codes	^{226}Ra	^{232}Th	^{40}K	^{137}Cs
S1	38.83	20.07	385.19	11.20
S2	37.17	28.37	613.11	2.76
S3	32.68	18.91	361.89	7.42
S4	29.13	22.75	418.73	6.59
S5	30.84	20.97	236.03	2.18
S6	33.71	21.63	266.99	2.53
S7	37.73	24.07	418.07	16.62
S8	35.18	22.60	535.07	17.92
S9	16.21	8.53	292.46	7.41
S10	33.73	15.19	261.81	7.13
Average± S.D.	32.52±6.48	20.30±5.36	378.93±123.29	8.17±5.55

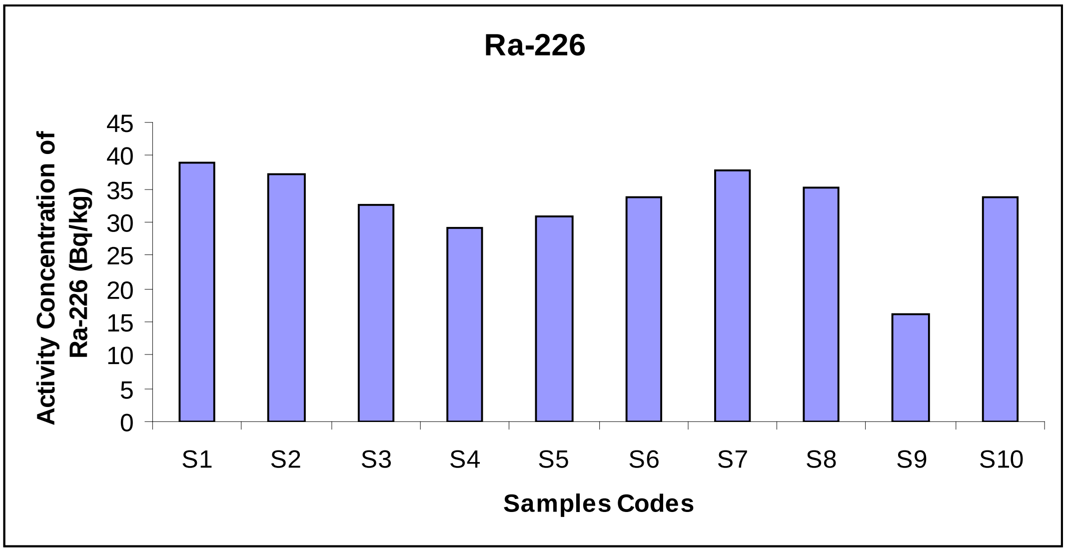

Figure 1. Activity concentration for ^{226}Ra in soil samples

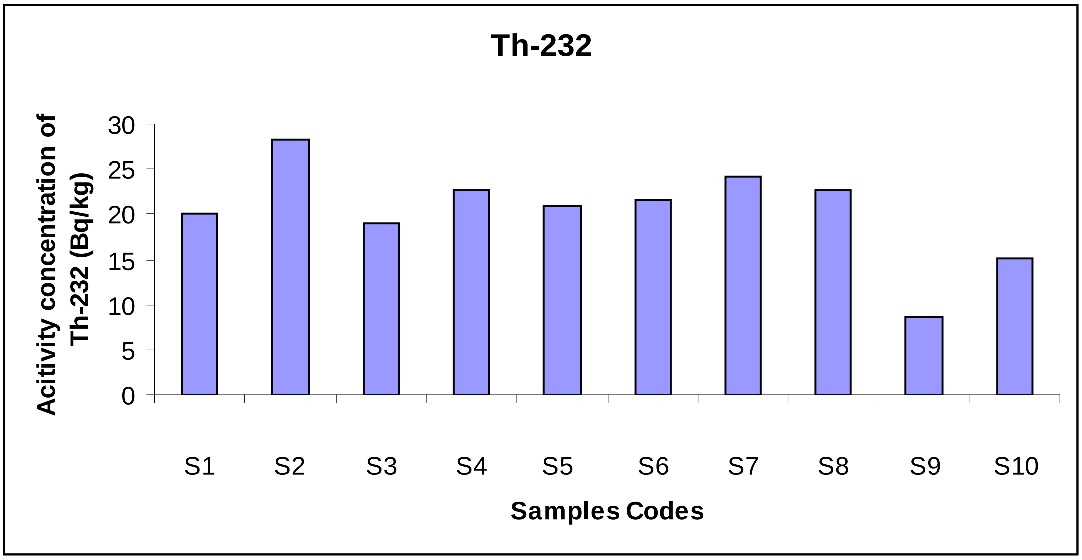

Figure 2. Activity concentration for ^{232}Th in soil samples

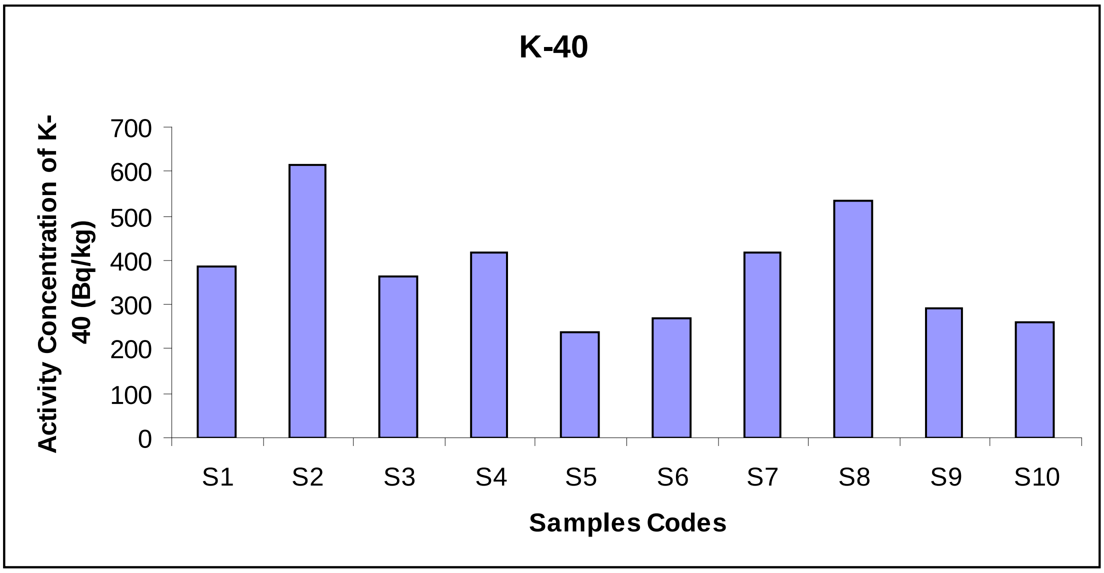

Figure 3. Activity concentration for ^{40}K in soil samples.

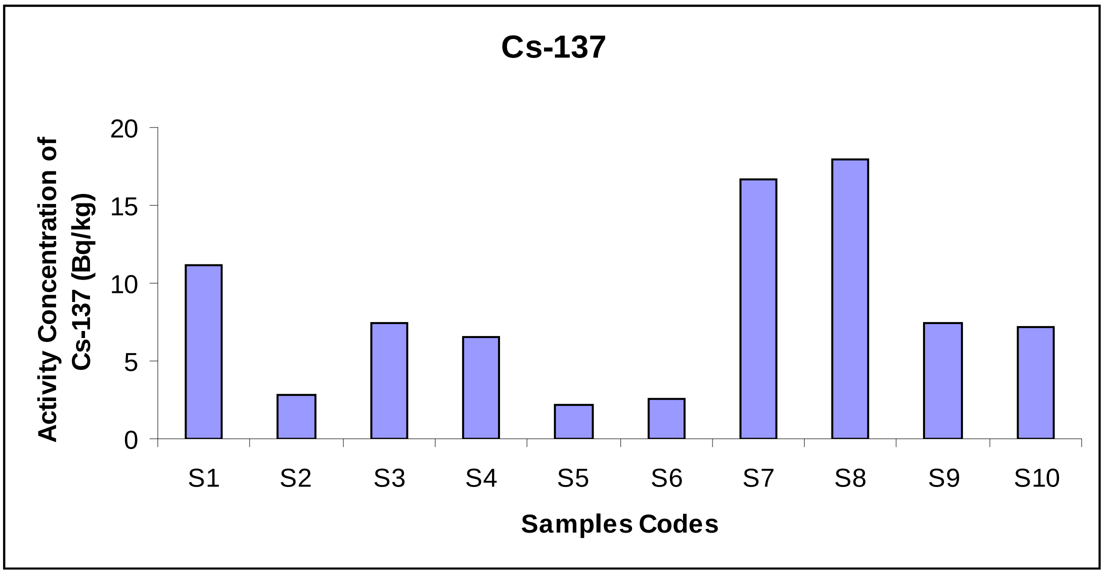

Figure 4. Activity concentration for ^{137}Cs in soil samples

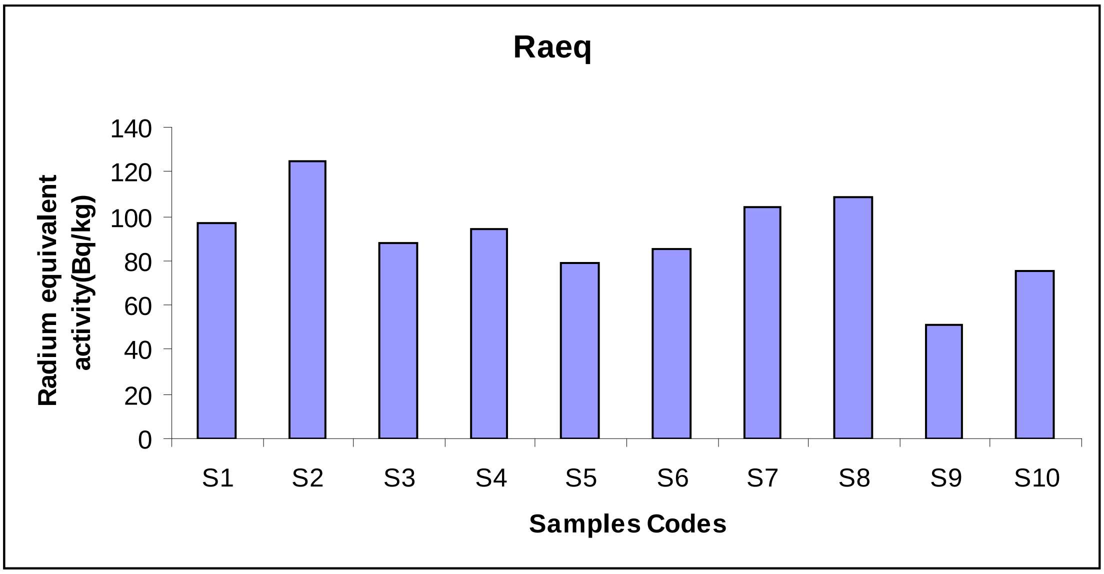

Figure 5. Bar graph showing the Radium equivalent activity R_{aeq} (Bq/kg) of soil samples in different districts.

3.2. Gamma Radiation Parameters

3.2.1. Radium Equivalent Activity (Ra_{eq})

The distribution of ^{226}Ra, ^{232}Th and ^{40}K in soil is not uniform. Uniformity with respect to exposure to radiation has been defined in terms of radium equivalent activity (R_{aeq}) in Bq/kg to compare the specific activity of the material containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K.It is calculated through the following relation [13]:

$$Ra_{eq}\left(Bq/kg\right) = A_{Ra} + 1.43A_{Th} + 0.077A_K \qquad (2)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively. While defining Raeq activity, it has been assumed that 370 Bq/kg of ^{226}Ra or 259 Bq/kg of ^{232}Th or 4810 Bq/kg of ^{40}K produce the same gamma dose rate. The results of radium equivalent activity shown graphically in fig.5.

3.2.2. Absorbed Gamma Dose Rate(D)

The external outdoor absorbed gamma dose rate due to terrestrial gamma rays from the nuclides ^{226}Ra, ^{232}Th and ^{40}K at 1m above the ground level were calculated as follows outlined by [14]:

$$D\left(nGy/h\right) = 0.462\,A_{Ra} + 0.604A_{Th} + 0.0417A_K \qquad (3)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg. Fig.6 shows graphically the results of absorbed gamma dose rate.

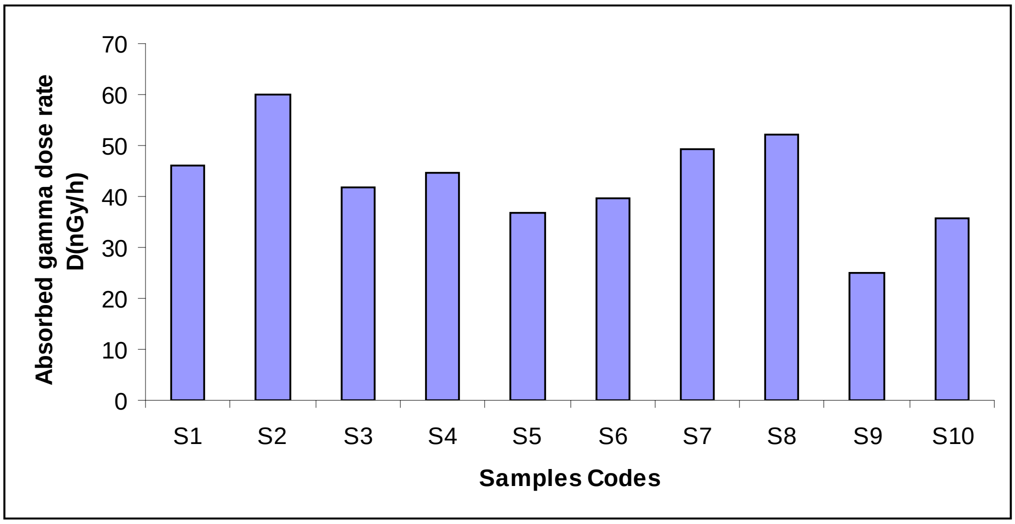

Figure 6. Bar graph showing the Absorbed gamma dose rate D(nGy/h) of soil samples in different districts.

3.2.3. External and Internal Hazard Indices (H_{ex} and H_{in})

Local soil of the area is used for the construction of houses. These soils will contribute to the external gamma dose rate in these houses. The external hazard index (H_{ex}) can be defined as follows [15]:

$$I_\gamma = A_{Ra}/150 + A_{Th}/100 + A_K/4810 \le 1 \qquad (4)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively. When the value of this index is less than unity then the radiation received by occupants will be < 1.5 mGy/y. The internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index(H_{in}), which is calculated by the relation [16]:

$$H_{in} = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \le 1 \qquad (5)$$

H_{in} should be <1 for safe use of soil.

The results of H_{in} and H_{ex} shown graphically in Figure 7.

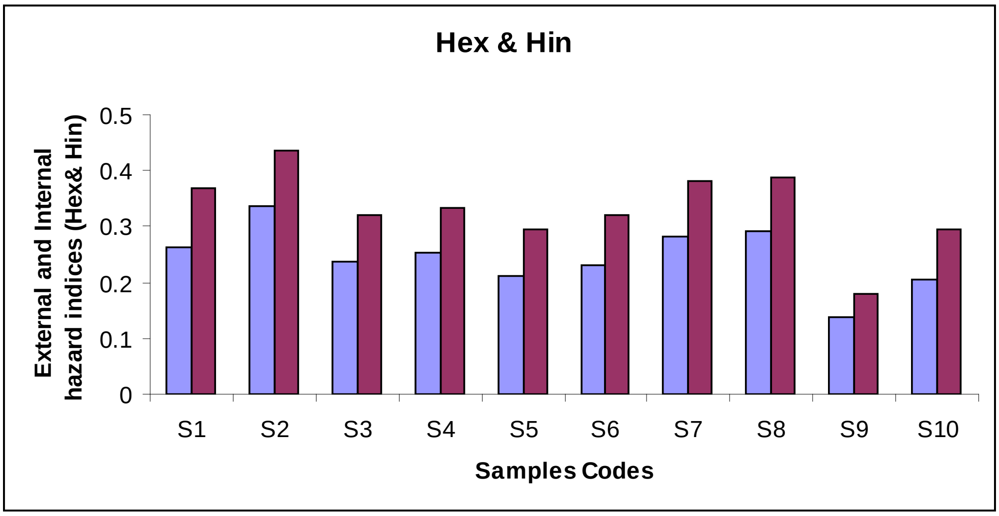

Figure 7. Bar graph showing the External and Internal hazard indices (H_{ex}& H_{in}) of soil Samples in different districts

3.2.4. Gamma Index (I_γ)

Another radiation hazard called the representative level index I_γ, is defend as follows [17,18]:

$$I_\gamma = A_{Ra}/150 + A_{Th}/100 + A_K/4810 \le 1 \quad (6)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively.

I_γ varied from 0.388 in S9 (Al-Medan district) to 0.940 in S2 (Rabeea district), with an average value of 0.65± 0.16.

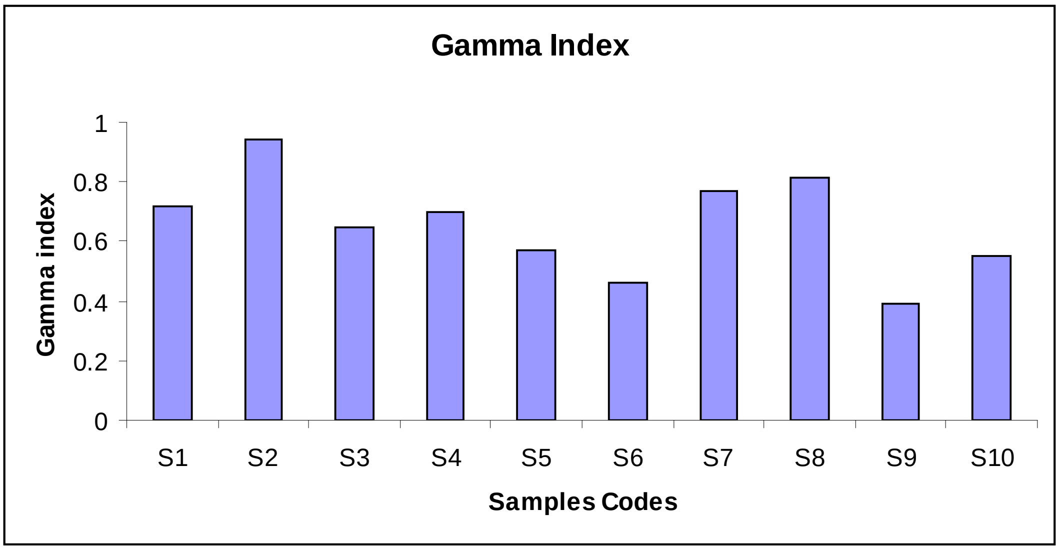

Figure 8. Bar graph showing the Gamma index (I_γ) of soil samples in different districts

This index value must be less than unity in order to keep the radiation hazard to be in significant. Fig.8 shows graphically the results of gamma index.

The results of radium equivalent activity(R_{aeq}), Absorbed dose rate(D), External and Internal hazard indices (H_{ex},H_{in}) and Gamma index (I_γ) are listed in Table 3.

Table 3. Radium equivalent activity(R_{aeq}), Absorbed dose rate (D), External and Internal hazard indices(H_{ex},H_{in}) and Gamma index(I_γ) for soil samples in selected districts in Nineveh province.

Samples Codes	R_{aeq}(Bq/kg)	D(nGy/h)	H_{ex}	H_{in}	I_γ
S1	97.18	46.12	0.262	0.367	0.716
S2	124.94	59.87	0.337	0.437	0.940
S3	87.58	41.61	0.236	0.322	0.648
S4	94.08	44.66	0.252	0.332	0.700
S5	79.00	36.75	0.213	0.296	0.572
S6	85.17	39.77	0.230	0.321	0.459
S7	104.34	49.40	0.281	0.383	0.770
S8	108.69	52.21	0.293	0.388	0.817
S9	50.92	24.83	0.137	0.181	0.388
S10	75.61	35.67	0.204	0.295	0.551
Average±S.D.	90.75±20.33	43.08±9.76	0.244±0.05	0.332±0.06	0.656±0.03

4. Conclusion

The evaluation of radiation hazard indices of soil samples in Nineveh province (IRAQ), has been conducted. The values obtained when compared with the various world permissible values world were found to be below the standards for such environment and soil from this area will pose no significant health threat to human lives and the environment is said to be radiogically hazard safe.

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