Novelty Journals

ISSN 2394-9651

International Journal of Novel Research in Physics Chemistry & Mathematics
Vol. 2, Issue 2, pp: (1-9), Month: May - August 2015, Available at: www.noveltyjournals.com

Assessment of Natural Radioactivity Level in Soil Samples for Selected Regions in Nineveh Province (IRAQ)

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Abstract: **The natural radioactivity in soil of Nineveh Province has been studied in this paper. The radioactivity of 19 soil samples were determined by gamma spectrometry using NaI (Tl) detector .The activity of radionuclide's, ^{238}U,232Th ,^{226}Ra and ^{40}K ranged from 21.25 to 58.13Bq/kg , 11.22 to 31.63Bq/kg, 17.02to 40.98 Bq/kg and from 206.51 to 509.56 Bq/kg respectively. The activity concentrations for these radionuclide's were compared with world average activity of soil, it found that the average of activity concentrations of ^{238}U and ^{226}Ra are higher than world average value while the activities of ^{232}Th and ^{40}K are found to be lower. In order to evaluate the radiological hazard of the natural radioactivity, the radium equivalent activity, the absorbed dose rate, the annual effective dose rate, internal and external hazard indices and finally, gamma index have been calculated. The study provides background radioactivity concentrations in Nineveh Province.**

Keywords: **Natural radioactivity, NaI(Tl) Detector, Radium Equivalent Activity, External Hazard, soil samples , Nineveh Province.**

1. INTRODUCTION

The radioactivity of components in the earth's crust is due to the presence of natural radioactive series (^{238}U, ^{235}U and ^{232}Th series) and ^{40}K [5],[19]. Natural sources are the largest contributor to the external dose of world population UNSCEAR [29] . These doses vary depending upon the concentration of the natural radionuclide's^{238}U and ^{232}Th,^{235}U their daughter products and^{40}K, present in soil and rocks, which in turn depend upon the local geology of the region in the world[24],[23],[22]&[8].There are many studies and researches which studied the natural radioactivity in the environmental, and we will show them, thirty four soil surface samples were collected from four directions in Armant area. Qena, Egypt by[14] to measure their natural radioactivity concentrations due to ^{226}Ra,^{232}Th and^{40}K radionuclide's. Soil samples were analyzed by using low-level gamma-ray spectrometric analysis .The average of activity concentrations for ^{226}Ra 27.3,11.4,10.6 and 11.4 Bq/kg while the average value for ^{232}Th was 15.1 ,11.1,10.8 and11.1 Bq/kg for soil samples from North, South, West and East .The corresponding average value for ^{40}K were 521,463,488.9and 344 Bq/kg respectively. The natural radioactivity due to presence of^{238}U,^{232}Th and ^{40}K radionuclide's in soil of Kufa zone, Najaf governorate ,Iraq were measured by (Ekal,2013)by using gamma-ray spectrometry Na(Tl) .The specific activity of the soil sample ranged from 1.76 to 77.45Bq/kg ,from 7.92 to 42.58 Bq/kg and from 219.58 to 1994.17 Bq/kg for ^{238}U,^{232}Th and ^{40}K respectively. The researchers in ref. [33] collected soil samples at five different depth (10,20,30,40 and 50)cm from some towns in the east of Sulaimany governorate ,Iraq , and measured the natural radioactivity concentration in soil sample by using gamma ray spectrometer using detector NaI(Tl),the average value in the topsoil(surface) of natural radionuclide's (^{238}U) concentration was 83.33 Bq/kg ,for ^{232}Th was 19.14 Bq/kg and for ^{40}K was 284.86 Bq/kg. The authors in[10] used NaI(Tl) gamma ray spectrometer to measured the activity concentration and the gamma absorbed dose rates of the terrestrial naturally occurring radionuclide's (^{226}Ra, ^{32}Th and ^{40}K) in soil samples collected from seven different locations of Qassim region in Saudi Arabia .The average of activity concentration of ^{226}Ra,^{232}Th and^{40}K found to be 9.5,12.3 and 535 Bq/kg respectively, and the mean value of total absorbed dose rate is 35.2nGy/h. The aim of this

work is to determine the activity concentration of the natural occurring radionuclide's (^{238}U ^{226}Ra, ^{232}Th and ^{40}K) in soil samples collected from different areas of Nineveh province. Also, the average equivalent activity(Ra_{eq}),total absorbed dose rate(D), annual effective dose equivalent(AEDE), the internal hazard index(H_{in}), the external hazard index (H_{ex}) and gamma index(I_{γ}).The results of this study will provide background data on the natural radioactive isotopes and environmental pollution.

2. MATERIAL AND METHOD

2.1. Study area

This study was carried out at Nineveh province. By selecting 11 districts from the center of Mosul city(i.e camp of Gazlany, Al-Medan, college of agriculture and behind the building of department of physics in the university of Mosul) and others from many of small towns outside of the Mosul city(Senjar, Telkaif,Telafar,Al-Hamdanea, Bahcheeka, Al-Koosh and Rabea'a),as shown in table 1.

Table1: Names and codes of the collected samples in Nineveh Province.

Samples no.	Samples names	Samples codes
1	Sinjar A	S1
2	Sinjar B	S2
3	Rabea'a A	S3
4	Rabea'a B	S4
5	Telfar A	S5
6	Telfar B	S6
7	Al-Koosh A	S7
8	Al-Koosh B	S8
9	Telkaif A	S9
10	Telkaif B	S10
11	Al-Hamdanea A	S11
12	Al-Hamdanea B	S12
13	Bahcheeka	S13
14	Camp of Gazlany A	S14
15	Camp of Gazlany B	S15
16	Al-Medan	S16
17	college of agriculture A	S17
18	college of agriculture B	S18
19	Department of physics	S19

2.2 Sampling and Samples preparing:

Nineteen soil samples were collected from all of the districts, everyone of these samples weigh about 1.5kg , and the stones, organic matter were removed from these samples. Then the samples dried by placing it in the oven of 110℃ about 24 h, then crushed to pass through 2 mm sieve to be homogenized in size. The homogenized soil samples were sealed in plastic containers and left for at least one month, before gamma spectrometric analysis, to attain secular equilibrium between radon and its decay products [26],[20]&[15].

2.3. Gamma spectrometry:

Gamma ray spectrometry analysis of the soil samples for natural radioactivity was carried out by using NaI(Tl) detector of radius (3.8cm) and thickness(2.5cm).The detector was interfaced to a PC-computer with a program installed for this purpose to make it equivalent to a multi-channel analyzer. The system also contains the usual electronic components of preamplifier, amplifier and power supply. The detector has resolution (FWHM) of (33.3keV) for the (1332 keV) γ-ray line of ^{60}Co. The γ-ray spectrometer energy calibration was performed using ^{137}Cs and ^{60}Co point source in a lead protected

Novelty Journals

ISSN 2394-9651

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box ,then the concentration of natural radionuclide's in these samples was determined from the peaks at 911 keV ^{228}Ac for ^{232}Th,the peak at 1765keV(^{214}Bi)for ^{238}U, the peak at 1460keV for ^{40}K and the peak at 609keV(^{214}Bi)for ^{226}Ra.

The activity concentration of ^{238}U ^{226}Ra, ^{232}Th and ^{40}K was calculated using the following relation [4]:

$$A = \frac{\sum N - \sum B.G}{\varepsilon . I . t . m} \qquad (1)$$

Where:

A: The activity concentration

$\sum N$: The net peak area at energy E of radionuclides ^{238}U ^{226}Ra, ^{232}Th and ^{40}K at presence the samples.

$\sum B.G$: The net peak area at energy E of radionuclides ^{238}U ^{226}Ra, ^{232}Th and ^{40}K for background radiation at the absence the samples.

ε : Gamma efficiency evaluated in function of the transition energy.

I: The absolute intensity of transition.

t : The sample counting time 10800 sec.

m: The weight of the sample 0.7kg.

3. RESULTS AND DISCUSSION

3.1. Activity concentrations of ^{238}U, ^{232}Th, ^{40}K and ^{226}Ra

Table (2) shows the activity concentrations of the main natural radionuclide's of the ^{238}U series , ^{232}Th series and ^{40}K in 19 soil samples in selected 11 districts in Nineveh province. From the table 2 ,it is observed that ,the activity concentration of ^{238}U , ranged from 21.25Bq/kg (Al-Medan) to 58.13Bq/kg(Department of physics) with an average 41.24Bq/kg, for the ^{232}Th concentration, ranged from 11.22Bq/kg (Al-Medan) to 32.65Bq/kg(Rabea'a B) with an average 21.52Bq/kg, while for ^{40}K activity concentration value ranged from206.51Bq/kg(Al-Koosh B) to 509.56Bq/kg(Rabea'a B)with an average 326.74Bq/kg ,and ^{226}Ra activity concentration values ranged from 17.02Bq/kg(Al-Medan) to 40.98 Bq/kg(Camp of Gazlany B) with an average 33.55Bq/kg. The average of activity concentration of present study area, activity for ^{238}U is higher than the world average value of 33Bq/kg, activity for ^{232}Th is lower than the world average value of 45 Bq/kg, activity of ^{40}K also lower than the world average value of 412Bq/kg but the activity of ^{226}Ra is higher than the world average value of 32 Bq/kg UNSCEAR [31].Other observation of table 2 is the activity concentration of ^{40}K is higher than the activity concentration of other radionuclide's such ^{226}Ra, ^{232}Th and ^{238}U for all districts. The reason of increase the concentration of ^{238}U and ^{226}Ra in some districts comparison with other districts are the exposure of these districts to the bombing in the war of 2003 on the Iraq. The activity concentration value of ^{238}U, ^{232}Th, ^{40}K and ^{226}Ra in the soil samples from some districts in Nineveh province are shown in fig.1.

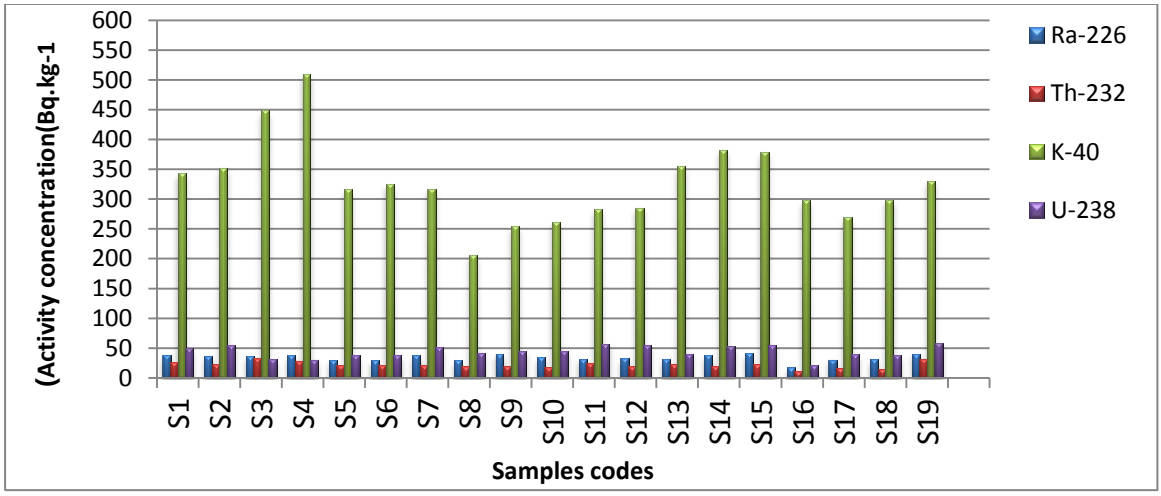

Fig.1: The activity concentration of ^{238}U, ^{232}Th, ^{40}K and ^{226}Ra for soil samples in some districts of Nineveh province.

Novelty Journals

ISSN 2394-9651

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Table 2 : The activity concentration of ^{238}U, ^{232}Th,^{40}K and ^{226}Ra in (Bq/kg) in soil samples at Nineveh province

Samples codes	(Activity concentration Bq/kg)			
	^{238}U	^{40}K	^{232}Th	^{226}Ra
S1	49.31	342.60	25.51	37.77
S2	53.67	352.38	22.95	36.56
S3	30.79	449.12	32.65	36.17
S4	29.97	509.56	28.57	37.35
S5	36.78	315.78	20.72	29.46
S6	38.14	324.31	21.26	28.96
S7	50.40	316.79	21.65	36.93
S8	41.68	206.51	18.63	29.22
S9	43.86	254.38	18.87	39.82
S10	44.95	260.40	17.85	34.12
S11	56.67	281.95	23.97	31.22
S12	54.22	285.21	18.87	32.09
S13	40.05	354.88	21.93	31.59
S14	52.31	382.20	19.89	37.14
S15	55.31	377.44	21.93	40.98
S16	21.25	296.99	11.22	17.02
S17	38.96	268.67	15.81	30.01
S18	37.60	298.49	14.98	31.17
S19	58.13	330.57	31.63	40.01
Average±S.D	41.24±10.24	326.74±70.26	21.52±5.37	33.55±5.61

The activity concentration of ^{238}U, ^{232}Th,^{40}K and ^{226}Rain soil samples from the studied areas have been compared with those from similar investigation in Iraq and other countries and summary results are given in table(3).It is found that the mean value of ^{238}U in the present study was lower than reported for soil of Northern India , Najaf-Iraq , Turkey and Jordan, but it was higher than for soil of Bangladesh, and it was found that the mean values of the concentration of $^{232}Th$was higher than reported for soil of Najaf-Iraq, Jordan and Saudi Arabia ,but it was lower than other countries in the table, while the concentration of ^{40}Kin soil samples of present study was lower than reported for soil of all countries except Jordan. Finally the concentration of ^{226}Ra in the present study was higher than that in the Baghdad-Iraq, Turkey, Saudi Arabia and Yemen, but it was lower than that in Northern India, Jordan and Iran.

The variations in the concentration of the radioactivity in the soil of various locations of the world depend upon the geological and geographical conditions of the area and the extent of fertilizer applied to the agriculture lands [11] .

Table 3: Comparison of natural radioactivity concentration (Bq/kg) in soil samples for present study with previous study reported from different countries of the world.

Country	Mean Activity Concentration (Bq/kg)				References
	^{238}U	^{232}Th	^{40}K	^{226}Ra	
Northern India	56.02	91.56	340.78	63.88	[27]
Najaf-Iraq	77.33	9.36	426.31	---	[3]
Turkey	55.42	22.86	1318	32	[2]
Jordan	57.7	18.1	138.4	44.9	[28]
Yemen	---	36.26	358.12	30.41	[13]
Baghdad-Iraq	---	21.74	434.67	25.81	[1]
Saudi Arabia	---	12.3	535	9.5	[10]
Iran	---	43.4	555.1	38.8	[6]
Bangladesh	30.93	61.65	467.8	---	[25]
Present study	41.24	21.52	326.74	33.55	-----
World average	33	45	412	32	UNSCEAR [31]

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3.2. Radiological parameters

3.2.1. Radium equivalent activity (Ra_{eq})

To represent the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them, a common radiological index has been introduced. The index is called radium equivalent activity (Ra_{eq}) which is used to ensure the uniformity in the distribution of natural radionuclide's ^{226}Ra, ^{232}Th and ^{40}K and is given by the expression [16] :

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

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

The calculated values are varied from 55.93Bq/kg (Al-Medan) to 117.44Bq/kg(Rabea'a B) with an average of 89.41Bq/kg (table 4).These values are lower than the permissible maximum value of 370 Bq/kg [21] .

3.2.2. External hazard index (H_{ex})

To limit the external gamma radiation dose, an extensively used hazard index, the external hazard index (H_{ex}) was calculated from the equation [32] .

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (3)$$

The values of outdoor radiation hazard index (H_{ex}) vary from 0.151 (Al-Medan) to 0.317 (Rabea'a B) with an average of 0.238, where all values are less than the critical values of unity

3.2.3. Internal hazard index (H_{in})

Radon and its short-lived products are also hazardous to the respiratory organs. So internal exposure to radon and its short-lived products is quantified by internal hazard index and is expressed mathematically as [7] .

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (4)$$

The calculated values of H_{in} are ranged from 0.197 (Al-Medan) to 0.418 (Rabea'a B) with an average of 0.329,this is lower than the recommended limit table (4).

3.2.4. Gamma Index(I_γ)

The gamma index (I_γ) for soil samples was calculated by using the following equation [17] .

$$I_\gamma = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \leq 1 \quad (5)$$

I_γ varies from 0.423 (Al-Medan) to 0.874 (Rabea'a B),with an average of (0.644), as listed in table 4.

The relation between the values of H_{ex}, H_{in} and I_γ are shown in fig.2.

The values of the hazard indices and gamma index should be less than unity in order to keep the radiation hazard to be insignificant. The maximum value of Hex equal to unity corresponds to the upper limit of radium equivalent activity R_{aeq} (370 Bq/ kg).

3.2.5. Gamma Absorbed Dose Rate (D)

The total air absorbed dose rate (nGy/h) in the outdoor air at 1 m above the ground due to the activity concentrations ^{238}U, ^{226}Ra and ^{40}K

(Bq/ kg) dry weight was calculated by using the following equation [18] .

$$D(nGy/h) = 0.427A_U + 0.5A_{Ra} + 0.041A_K \quad (6)$$

The absorbed dose in the study area ranges from 29.76nGy. h^{-1} (Al-Medan) to 59.58 nGy. h^{-1} (Camp of Gazlany B) with an average of 48.91nGy. h^{-1}, which is lower than the permissible maximum values of 51 nGy. h^{-1} reported by UNSCEAR [30].The calculated total absorbed dose rate D(nGy/h) are listed in table(4).

3.2.6. Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent AEDE (μSv/ y) in air was calculated using the values of the absorbed dose rate by applying the dose conversion factor of 0.7 Sv/Gy and the outdoor occupancy factor of 0.2 (people spend about 20% of their life outdoor).The Annual Effective Dose (in μSv/y) received by population can be calculated by using equation UNSCEAR [30] .

$$AEDE\ (\mu Sv/y) = D\ (nGy/h) \times 8{,}760\ h \times 0.7(Sv/Gy) \times 0.2 \times 10^{-3} \qquad (7)$$

Where**:** D (nG/h) is the total air absorbed dose rate in the outdoor. 8,766 h is the number of hours in 1 year. 10^{-3} conversion factor to micro. As shown in table (4), the annual effective dose equivalent from outdoor terrestrial gamma radiation ranged from36.53 μSv/y(Al-Medan) to 73.06 μSv/y(Camp of Gazlany B),with a mean values of59.99μSv/y, which is lower than the permissible maximum values of 460μSv/y reported by UNSCEAR [30]. Fig.3 shows a histogram of the radium equivalent, absorbed dose rate and annual effective dose equivalent for different soil sample from Nineveh province.

Table 4: Radium equivalent activity, absorbed dose rate, annual effective dose equivalent, internal and external hazard indices and gamma index for collected soil samples in Nineveh province.

Samples code	Ra_{eq}(Bq/kg)	D(nGy/h)	AEDE(μSv/y)	H_{in}	H_{ex}	I_γ
S1	100.62	53.98	66.20	0.373	0.271	0.735
S2	96.51	55.64	68.23	0.359	0.260	0.708
S3	115.98	49.64	60.87	0.411	0.313	0.856
S4	117.44	52.36	64.21	0.418	0.317	0.874
S5	83.40	43.38	53.20	0.304	0.225	0.614
S6	84.33	44.06	54.03	0.306	0.227	0.621
S7	92.28	52.97	64.96	0.349	0.249	0.673
S8	71.76	40.87	50.12	0.272	0.193	0.518
S9	86.39	49.06	60.16	0.341	0.233	0.623
S10	79.69	46.93	57.55	0.307	0.215	0.579
S11	87.20	51.36	62.98	0.319	0.235	0.635
S12	81.03	50.89	62.52	0.251	0.164	0.452
S13	90.27	47.44	58.18	0.329	0.243	0.666
S14	95.01	56.57	69.37	0.357	0.256	0.701
S15	101.40	59.58	73.06	0.384	0.273	0.744
S16	55.93	29.76	36.53	0.197	0.151	0.423
S17	73.30	42.65	52.30	0.279	0.198	0.537
S18	75.57	43.87	53.80	0.288	0.204	0.556
S19	110.69	58.45	71.68	0.407	0.299	0.803
Average±S.D	89.41±15.68	48.91±7.1	59.99±8.8	0.329± 0.05	0.236± 0.04	0.648± 0.12

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ISSN 2394-9651

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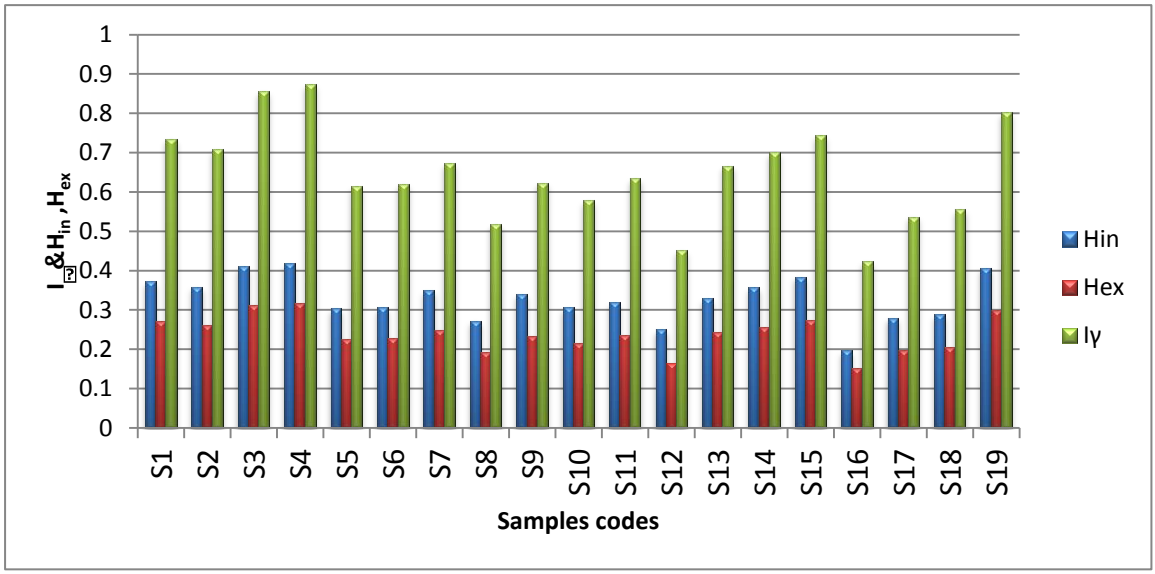

Fig.2 The hazard indices (Hin, Hex) and Iγ of different soils samples from Nineveh province.

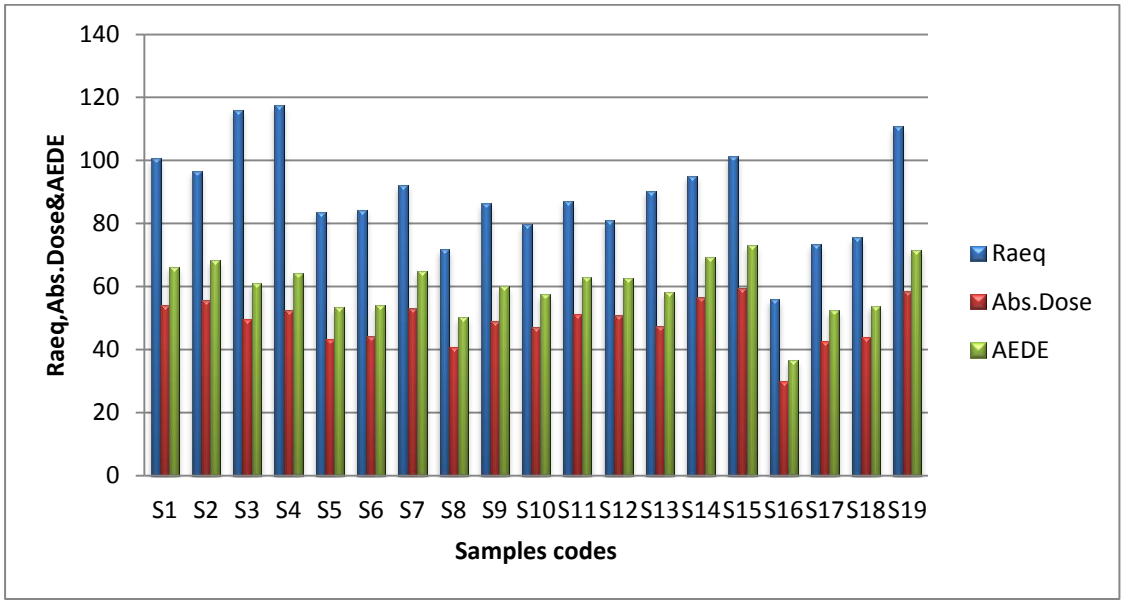

Fig.3 Average activity radium equivalent, absorbed dose rate and annul effective dose equivalent of different soil samples from Nineveh province.

4. CONCLUSIONS

It is important to determine background radiation level in order to evaluate the health hazard. The results of the average activity concentrations of(^{238}Uand ^{226}Ra) for 19 soil samples collected from 11 districts from Nineveh province were higher than the permissible maximum values reported by world average ,but the average activity concentrations of (^{232}Th and ^{40}K) were lower than the permissible maximum values reported by world average. The results of the present work concerning values of radium equivalent activity, outdoor annual effective dose rates, the gamma index, internal and external hazard indices, all were found to be lower than their corresponding allowed limits given by world average. The data produced in the present work can be used as baseline radiological data for future investigations.

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