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ASSESSMENT OF NATURAL RADIOACTIVITY OF SOIL IN NEW ASSIUT CITY AND RADIOLOGICAL HAZARDS THAT EXPOSED POPULATION

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The activity concentrations of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K and radiological hazards for soil samples from New Assiut City have been measured by using gamma spectrometry (HPGe) detector. The measured average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were 20.50±1.28 Bq.kg^{-1}, 16.37±2.077 Bq.kg^{-1} and 189.51±0.34 Bq.kg^{-1} respectively. The activity concentrations from this study were compared with the reported data from other countries.

The Ra_{eq} values of all samples were lower than the limit of 113 Bq.kg^{-1}, equivalent to a gamma dose of 1.5 mSv.a^{-1} recommended by OECD. With average annual dose 0.07 mSv.y^{-1}, this value is about 7 % of the 1.0 mSv.y^{-1} which is recommended as the maximum annual dose per person by the International Commission on Radiological Protection.

Key words: Radiological pollution, Radiation in Soil , total annual dose , (HpGe) detector

1. INTRODUCTION

Natural radionuclides exist in soil generate a significant component of the background radiation that humans exposure to. A significant contribution to total radiation dose from natural sources comes from terrestrial radionuclides such as ^{238}U, ^{232}Th and ^{40}K. The natural radioactive material in soil account for about 28 millirem or about 8% of the radiation

dose which a person typically receives in a year from all radiation sources including medical exposures [1], [2], [3].

The Earth's crust contains small amounts of uranium, thorium and radium in addition to radioactive isotopes of several elements including potassium. The radiation dose comes from gamma rays, which are emitted from rocks, soil and some building materials. It is important to estimate the exposures of humans to the various sources of radiation [4], [5].

New Assiut City is a new city which planned to be populated with 750 thousand resident, In the present work we will determine the natural radioactivity concentration levels of the city soil and radiological hazards that exposed population, which could be used as reference information to assess any changes in the natural radioactivity levels.

2. MEASUREMENT EQUIPMENT AND METHODOLOGY

2.1. Samples Collection

Fifty soil samples were collected, from New Assiut City, the Area for New Assiut City is about 15 km^2 , we divided it into 50 equal areas 600 m × 500 m for each, which is 0.3 km^2 , and take a soil sample from each divided area.

All descriptions of these samples are summarized in table (1) and Fig. (1) which illustrate the position of them.

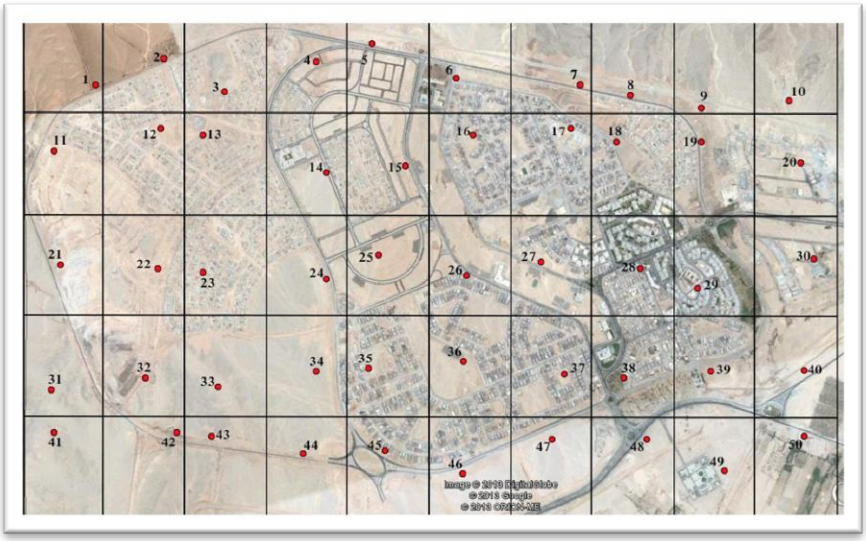

Figure 1: Map of NewAssiut city illustrate the location of sample

Table 1: Number and Location of collected samples

No. Of Samples	Coordinates	
	North	East
1	27°17'33.75"N	31°16'8.32"E
2	27°17'33.11"N	31°16'25.17"E
3	27°17'22.19"N	31°16'35.05"E
4	27°17'21.07"N	31°16'57.54"E
5	27°17'19.85"N	31°17'10.29"E
6	27°17'7.34"N	31°17'25.22"E
7	27°16'55.87"N	31°17'50.92"E
8	27°16'50.34"N	31°17'59.52"E
9	27°16'43.90"N	31°18'13.47"E
10	27°16'36.33"N	31°18'34.18"E
11	27°17'25.00"N	31°15'54.27"E
12	27°17'20.84"N	31°16'18.32"E
13	27°17'17.11"N	31°16'28.30"E
14	27°17'0.55"N	31°16'49.75"E
15	27°16'54.87"N	31°17'7.06"E

16	27°16'55.89"N	31°17'23.91"E
17	27°16'48.50"N	31°17'44.37"E
18	27°16'42.96"N	31°17'53.39"E
19	27°16'35.30"N	31°18'10.78"E
20	27°16'24.31"N	31°18'29.80"E
21	27°17'3.65"N	31°15'46.28"E
22	27°16'57.24"N	31°16'5.48"E
23	27°16'50.89"N	31°16'15.81"E
24	27°16'39.35"N	31°16'41.25"E
25	27°16'41.18"N	31°16'53.79"E
26	27°16'31.14"N	31°17'10.18"E

Table 1: Continue

No. Of Samples	Coordinates	
	North	East
27	27°16'27.12"N	31°17'26.76"E
28	27°16'18.22"N	31°17'47.47"E
29	27°16'10.53"N	31°17'57.18"E
30	27°16'6.59"N	31°18'24.52"E
31	27°16'44.28"N	31°15'37.16"E
32	27°16'36.43"N	31°15'55.83"E
33	27°16'30.65"N	31°16'9.97"E
34	27°16'24.44"N	31°16'32.56"E
35	27°16'21.62"N	31°16'42.17"E
36	27°16'15.75"N	31°17'2.21"E
37	27°16'5.38"N	31°17'22.60"E
38	27°16'0.69"N	31°17'34.12"E
39	27°15'55.10"N	31°17'52.15"E
40	27°15'47.28"N	31°18'13.48"E

41	27°16'31.23"N	31°15'30.30"E
42	27°16'24.61"N	31°15'57.06"E
43	27°16'20.81"N	31°16'4.68"E
44	27°16'11.21"N	31°16'22.73"E
45	27°16'5.60"N	31°16'38.99"E
46	27°15'55.36"N	31°16'53.10"E
47	27°15'55.38"N	31°17'14.24"E
48	27°15'47.24"N	31°17'33.70"E
49	27°15'35.79"N	31°17'46.83"E
50	27°15'35.75"N	31°18'6.29"E

2.2. Sample preparation:

To prepare the samples the following steps must be taken into account:

- The soil was taken to the laboratory from a collection spot wrapped in plastic bags.
- The soil samples were crushed, homogenized, and sieved through a 200 μm which are the optimum size enriched in heavy minerals
- Each sample was dried in an oven at 110 °C for 48 hours to ensure that moisture is completely removed.
- Weighted samples were placed in beaker The containers were thick enough to prevent the permeation of radon
- The containers were filled with the samples and the net weight of the samples was noted by subtracting the weight of empty containers.
- The containers were closed by screw caps and the plastic tape was wrapped over the caps
- Finally, the beakers were completely sealed for four weeks, which is the time taken for the short-lived daughters of ^{226}Ra and ^{232}Th to come into equilibrium with the parent ^{226}Ra and ^{232}Th.

The previous steps are necessary to ensure that radon gas confined within the volume and the daughters will also remain in the samples. [6]

2.3. Radiometric Analysis:

For gamma spectrometry analysis, all soil samples were analyzed after collection by low-background gamma spectroscopy using HPGe detector (Canberra, GR4020 model) with relative efficiency 40% for 3″ x 3″ NaI(Tl) crystal, and energy resolution of 2 keV at the 1332 keV gamma of ^{60}Co. The detector was shielded in a 6.22 cm thick lead well internally lined with 0.6 mm Carbon composite. The detector output was connected to a spectroscopy amplifier (Canberra, Model, 2002CSL). The energy calibration for the system is carried out using point sources of (^{133}Ba, ^{60}Co, ^{137}Cs, ^{54}Mn, ^{22}Na, and ^{65}Zn). This spectrometer was equipped with LabSOCSs (Laboratory Source less Calibration Software). Basic calibration measurements had been done at the factory; results were used to establish the detector's characterization file. The LabSOCSs calibration tool takes into account the sample to detector geometry, sample density and composition, as well as measurement container properties. To validate and check the efficiency data supplied by LabSOCSs, measurements were performed in our laboratory by using a set of calibrated point sources,(^{133}Ba, ^{60}Co and ^{137}Cs) positioned at a distance between 0 and 15 cm from the detector end-cap. The calculated results show good agreement between mathematical and empirical peak efficiencies with differences less than 10%.

For spectral analysis, the software Genie 2000 (Canberras, USA) has been used. The counting time of the measurements was 28800 s for activity or background. To determine the background radiation level, an empty cylindrical beaker was counted at the same time as the samples under identical geometry. The background spectra were used to correct the net peak area of gamma rays of measured isotopes. The ^{226}Ra radionuclide have been estimated from the 351.9keV (36.7 %) gamma peak of ^{214}Pb and 609.3keV (46.1 %), 1120.3keV (15 %) and 1764 keV (15.9 %) gamma peaks of ^{214}Bi. On the other hand the ^{232}Th radionuclide was estimated from the 911.2 keV (29 %) gamma peak of ^{228}Ac, the 238.6keV (43.6 %) gamma peak of ^{212}Pb and 2614 keV gamma ray from ^{208}Tl . While the ^{40}K radionuclide was estimated using the 1461 keV (10.7 %) gamma peak from ^{40}K itself. [7]

2.4. Activity Concentration:

The calculations of the activity concentration (Ac) values for radionuclides from ^{226}Ra, ^{232}Th and ^{40}K present in soil samples can be determined as:

$$AC = \frac{C_{net}}{\gamma \times \varepsilon \times m \times t}$$

Where C_{net} represent peak net counts, γ represent the emission probability of specific energy peak, ε is the absolute efficiency of the full energy peak of the detector, m is the mass of sample in Kg and t is the time of count. [8]

2.5. The Radium Equivalent Activity:

The distribution of ^{226}Ra, ^{232}Th and ^{40}K in soil is not uniform. Uniformity with respect to radiation exposure have been defined in terms of radium equivalent activity (Ra_{eq}) in Bq.kg^{-1} that's to compare the specific activity of materials containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K. It is calculated through the following equation:

$$Ra_{eq}=C_{Ra}+1.43C_{Th}+0.077C_{k} \quad [6]$$

Where C_{Ra}, C_{Th} and C_K, are the activity concentrations (in Bq.kg^{-1}) of radium, thorium and potassium, respectively.

The radium equivalent activities (Ra_{eq}) have been calculated on the estimation that 370 Bq.kg^{-1} (10 pCi^{-1}) ^{226}Ra, 259 Bq.kg^{-1} (7 pCi g^{-1}) ^{232}Th or 4810 Bq.kg^{-1} (130 pCi g^{-1}) ^{40}K produce the same dose rate of gamma-ray. [9], [10], [11]

2.6. Absorbed Dose Rate

The absorbed dose rate (in units nGyh^{-1} per Bq.kg^{-1}) for ^{226}Ra, ^{232}Th and ^{40}K are given for different materials. Dose rate indoors is calculated according to the EC (1999) for materials under investigation, through the following equation:

$$D = 0.12*C_{Ra}+0.14*C_{Th}+0.0096*C_K \quad [12], [13], [14]$$

Where C_{Ra}, C_{Th} and C_K, are the activity concentrations (in $Bq.kg^{-1}$) of radium, thorium and potassium, respectively.

2.7. Internal and External Hazard

Radon and its short-lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter's products are quantified by the internal hazard index (H_{in}), which is determined by the following equation:

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \leq 1 \quad [9], [15]$$

Where C_{Ra}, C_{Th} and C_K, are the activity concentrations (in $Bq.kg^{-1}$) of radium, thorium and potassium, respectively, the external gamma radiation exposure is quantified by the external hazard index (H_{ex}), which is determined by the following equation:

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \leq 1 \quad [9]$$

Where C_{Ra}, C_{Th} and C_K, are the activity concentrations (in $Bq\ kg^{-1}$) of radium, thorium and potassium, respectively.

2.8. Gamma Index (Iγ)

A number of indices dealing with the assessment of the excess gamma radiation arising from soil. The gamma-index (I_γ) was calculated as proposed by the following European Commission:

$$I_\gamma = 0.0067 * C_{Ra} + 0.01 * C_{Th} + 0.00067 * C_K \quad [12]$$

Where C_{Ra}, C_{Th} and C_K, are the activity concentrations (in $Bq.kg^{-1}$) of radium, thorium and potassium, respectively.

2.9. Annual Effective Dose (AED)

Finally, the annual effective dose rate (AED) in ($mSv.y^{-1}$) due to gamma radiation from soil , resulting from the concentrations of radionuclides in the environment due to terrestrial gamma radiation from ^{238}U, ^{232}Th and ^{40}K, could be determined by the average indoor conversion coefficient from absorbed dose rate (D) in the air and the

average annual effective dose equivalent (AED). The value of the conversion factor is 0.8 SvG.y^{-1} for gamma ray exposure in the environment and the occupancy factor outdoor to be about 0.2. The indoor AED can be calculated as follows:

$$AEDE_{in}\left(\mu Svy^{-1}\right) = D\left(nGyh^{-1}\right)\times 8760h\times 0.7SvGy^{-1}\times 0.8\times 10^{-3} \quad [5]$$

3. RESULTS AND DISCUSSIONS

3.1. Activity concentrations

The activity concentrations (Bq.kg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K of fifty soil samples collected from New Assiut City are given in table (2). The measured activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were varied from 9.02±1.12 to 51.64±1.09 and from 9.69±2.87 to 32.66±1.93 and from 108.15±0.41 to 290.73±0.28 respectively, with average activity concentrations 20.50±1.28 Bq.kg^{-1}, 16.37±2.077 Bq.kg^{-1} and 189.51±0.34 Bq.kg^{-1} respectively.

Table 2: Average Radioactivity Concentration in Soil Samples

Samples	Ra-226	Th-232	K-40
1	30.86±0.96	25.88±1.66	260.69±0.30
2	11.41±1.78	13.29±2.02	190.49±0.32
3	23.28±1.28	17.96±2.67	161.21±0.39
4	27.13±1.55	18.39±2.52	164.96±0.48
5	12.77±1.56	11.29±2.25	140.24±0.36
6	13.87±2.83	9.69±2.87	136.76±0.46
7	20.24±1.83	18.18±2.27	229.41±0.40
8	22.21±1.39	17.55±2.11	182.75±0.38
9	34.61±1.09	22.61±2.11	183.63±0.38
10	23.31±1.20	19.33±2.54	226.31±0.31
11	22.89±1.41	17.76±2.44	220.19±0.38
12	17.77±1.50	13.20±2.16	162.67±0.36
13	10.77±0.17	10.80±2.48	125.66±0.40
14	18.50±1.65	14.83±2.18	155.30±0.39
15	22.88±1.03	17.69±1.66	215.12±0.29

16	19.00±1.20	12.70±2.03	141.57±0.34
17	9.02±1.12	10.32±2.48	113.52±0.39
18	22.84±1.51	19.38±2.30	197.55±0.42
19	34.86±1.31	20.76±2.16	193.78±0.41
20	17.14±1.23	14.95±1.70	171.23±0.30
21	12.46±0.92	9.93±2.50	108.15±0.41
22	28.81±1.13	22.90±1.91	243.69±0.34
23	17.30±1.71	14.45±2.40	170.06±0.41
24	15.32±1.63	12.41±2.91	150.20±0.32
25	23.79±1.23	18.17±1.92	209.62±0.33
26	11.58±2.23	11.77±2.90	193.99±0.45

Table 2: Continue

Samples	Ra-226	Th-232	K-40
27	21.50±1.27	17.86±1.92	178.73±0.36
28	18.31±1.48	11.47±2.75	160.74±0.42
29	13.98±1.12	13.49±1.64	232.17±0.26
30	17.35±1.20	13.37±2.10	173.72±0.33
31	15.25±1.14	15.72±1.83	169.63±0.27
32	51.64±1.09	32.66±1.93	177.72±0.39
33	22.29±0.88	17.75±1.47	177.80±0.26
34	25.83±1.08	21.29±1.75	251.96±0.31
35	21.76±1.39	19.01±1.97	211.73±0.35
36	21.58±1.15	16.16±1.86	217.35±0.31
37	16.63±1.04	14.13±1.50	160.07±0.26
38	16.25±1.37	12.45±2.60	197.77±0.34
39	29.10±0.86	26.55±1.49	290.73±0.28
40	23.19±1.13	17.26±1.83	258.89±0.30
41	19.46±1.44	16.55±1.88	162.08±0.35
42	20.07±1.03	16.04±1.74	194.21±0.29
43	14.10±1.56	12.98±1.75	180.09±0.29
44	28.25±0.97	24.39±1.55	182.63±0.29
45	12.23±1.61	10.92±2.42	252.31±0.32
46	22.27±1.21	16.79±1.77	143.81±0.37

47	26.12±1.16	18.85±2.34	233.92±0.32
48	13.64±0.81	13.79±1.36	175.50±0.25
49	13.43±1.06	11.85±1.67	218.80±0.26
50	16.61±0.94	11.06±1.64	224.90±0.26
Min	9.02±1.12	9.69±2.87	108.15±0.41
Max	51.64±1.09	32.66±1.93	290.73±0.28
Mean	20.88±1.28	16.44±2.09	188.47±0.35

3.2. Radiation Hazards

3.2.1 The Radium Equivalent Activity

The values of radium equivalent Ra_{eq} ($Bqkg^{-1}$) for soil samples collected from New Assiut City were listed in Table (3). The lowest average value of Ra_{eq} is 32.52 $Bq.kg^{-1}$ in sample No. 17 with coordinates 27°16'48.50"N, 31°17'44.37"E, while the highest average of Ra_{eq} is 112.02 $Bq.kg^{-1}$ in sample No. 32 with coordinates 27°16'36.43"N, 31°15'55.83"E. These values are less than the maximum admissible value of 370 $Bq.kg^{-1}$. [5]

3.2.2 The Absorbed Dose Rate

As shown in the table (3), the values of absorbed dose rates due to ^{226}Ra, ^{232}Th and ^{40}K, ranged from 15.14 to 50.99 $nGy.h^{-1}$. These values are lower than the international limit of 59 $nGy.h^{-1}$. [5]

3.2.3 The Internal and External Hazards

The internal and external hazards values for soil samples collected from New Assiut City are lower than the unity (permissible level). [5]

3.2.4 Gamma Index (Iγ)

The values of the gamma activity index were ranged from 0.11 to 0.38 It is observed that all samples have gamma index Iγ < 2 which indicates gamma dose contribution from these soil samples did not exceed 0.3 mSv.y^{-1}.[16], [17]

3.2.5 Annual Effective Dose (AED)

The indoor annual effective doses (AED) from measured soil samples varied from 74.30 μSv.y^{-1} to 250.33 μSv.y^{-1}. These values are less than the world average of 450 μSvy^{-1}. [6], [18], [19]

Table 3. The Radiation Hazards Indices of the Samples

Samples	Ra_{eq}(BqKg^{-1})	Absorbed dose nGy/h	H_{in}	H_{ex}	Gamma index	AEDE (in) μSv/y
1	87.93	40.76	0.32	0.24	0.30	200.07
2	45.08	21.24	0.15	0.12	0.15	104.27
3	61.38	28.33	0.23	0.17	0.21	139.06
4	66.12	30.52	0.25	0.18	0.22	149.81
5	39.72	18.57	0.14	0.11	0.13	91.15
6	38.26	17.96	0.14	0.10	0.13	88.19
7	63.90	29.90	0.23	0.17	0.22	146.77
8	61.38	28.48	0.23	0.17	0.21	139.82

Table 3. Continue

Samples	Ra_{eq}(BqKg^{-1})	Absorbed dose nGy/h	H_{in}	H_{ex}	Gamma index	AEDE (in) μSv/y
9	81.08	37.30	0.31	0.22	0.27	183.12
10	68.37	31.88	0.25	0.18	0.23	156.49
11	65.23	30.48	0.24	0.18	0.22	149.63
12	49.16	22.96	0.18	0.13	0.17	112.72
13	35.88	16.74	0.13	0.10	0.12	82.16
14	51.66	23.98	0.19	0.14	0.17	117.72
15	64.74	30.23	0.24	0.17	0.22	148.38
16	48.07	22.36	0.18	0.13	0.16	109.75
17	32.52	15.14	0.11	0.09	0.11	74.30
18	65.75	30.49	0.24	0.18	0.22	149.68

19	79.47	36.73	0.31	0.21	0.27	180.29
20	51.70	24.09	0.19	0.14	0.17	118.24
21	34.98	16.26	0.13	0.09	0.12	79.83
22	80.32	37.30	0.29	0.22	0.27	183.12
23	51.06	23.81	0.18	0.14	0.17	116.89
24	44.62	20.83	0.16	0.12	0.15	102.27
25	65.91	30.70	0.24	0.18	0.22	150.73
26	43.35	20.55	0.15	0.12	0.15	100.87
27	60.80	28.17	0.22	0.16	0.21	138.30
28	47.10	22.09	0.18	0.13	0.16	108.45
29	51.15	24.29	0.18	0.14	0.17	119.24
30	49.84	23.33	0.18	0.13	0.17	114.53
31	50.79	23.61	0.18	0.14	0.17	115.92
32	112.02	50.99	0.44	0.30	0.38	250.33
33	61.37	28.44	0.23	0.17	0.21	139.60
34	75.67	35.30	0.27	0.20	0.26	173.28
35	65.24	30.36	0.24	0.18	0.22	149.05
36	61.42	28.79	0.22	0.17	0.21	141.34
37	49.16	22.89	0.18	0.13	0.17	112.37
38	49.28	23.27	0.18	0.13	0.17	114.25
39	89.45	41.60	0.32	0.24	0.30	204.23

Table 3. Continue

Samples	**$Ra_{eq}(BqKg^{-1})$**	**Absorbed dose nGy/h**	**H_{in}**	**H_{ex}**	**Gamma index**	**AEDE (in) µSv/y**
40	67.82	31.94	0.25	0.18	0.23	156.79
41	55.61	25.75	0.20	0.15	0.19	126.40
42	57.97	27.06	0.21	0.16	0.20	132.84
43	46.54	21.87	0.16	0.13	0.16	107.35
44	77.19	35.40	0.28	0.21	0.26	173.76
45	47.27	22.77	0.16	0.13	0.16	111.76
46	57.35	26.42	0.22	0.15	0.19	129.72
47	71.09	33.21	0.26	0.19	0.24	163.03

48	46.88	21.95	0.16	0.13	0.16	107.75
49	47.23	22.49	0.16	0.13	0.16	108.45
50	49.74	23.73	0.18	0.13	0.17	119.24
Min	32.52	15.14	0.11	0.09	0.11	74.30
Max	112.02	50.99	0.44	0.30	0.38	250.33
Mean	58.51	27.27	0.21	0.16	0.20	133.85

3.3 Comparison of Activity Concentrations with Similar Studies in other Countries:

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil samples which have been estimated from this study were compared with those from similar investigations in other regions and countries as shown in the table (4). As can be seen from Table (4), the mean values of ^{226}Ra, ^{232}Th and ^{40}K in soil were in the range of the corresponding values in the listed regions and countries.

Table 4: Comparison between Average Activity Concentrations of Investigated Samples with those in other Regions and Countries.

Country/Region	Activity ($Bq.Kg^{-1}$)			Ref.
	226Ra	232Th	40K	
Egypt (New Assiut)	**20.88**	**16.44**	**188.47**	**Present work**
Egypt (Aswan)	16.92	21.96	505.92	[8]
Egypt (Abou Zabal region)	31.12	10.96	264.1	[9]
Egypt (Alexandria)	16.43	18.31	268.16	[10]
United States	40	35	370	[3]
India	29	64	400	[3]
China	32	41	440	[3]
Japan	33	28	310	[3]
Iran	28	22	640	[3]
Denmark	17	19	460	[3]
Spain	32	33	470	[3]
World wide	35	35	400	[11]

4. CONCLUSION

The results showed that activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K are relatively low. And all radiological hazards indicates that the soil in New Assiut City is safe for individuals living there, and the radiation exposure is not significant.

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تقدير النشاط الإشعاعي الطبيعي في تربة مدينة أسيوط الجديدة ومخاطر الإشعاع التي يتعرض لها السكان

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يهدف هذا البحث إلى تقدير نسب بعض العناصر المشعة طبيعياً و هي (الراديوم-٢٢٦ و الثوريوم-٢٣٢ و البوتاسيوم-٤٠) في عينات من التربة بتوزيع جغرافي متناسب من مدينة أسيوط الجديدة ، و كذلك تقدير المخاطر الإشعاعية التي يتعرض لها السكان ، و ذلك من خلال:

- قياس تركيز النويات المشعة طبيعيا (الراديوم-٢٢٦ و الثوريوم-٢٣٢ و البوتاسيوم-٤٠) في العينات محل الدراسة .
- قياس المخاطر الإشعاعية الناتجة من التعرض لأشعة جاما المنبعثة من تلك النويات

و تلك المخاطر هي :

- المكافيء الراديومي (R_{eq})
- الجرعة الممتصة (D)
- معامل الخطر الإشعاعي الخارجي (H_{ex})
- معامل الخطر الإشعاعي الداخلي (H_{in})
- معامل جاما (I_{γ})
- متوسط الجرعة المكافئة السنوية (AEDE)

و لإجراء هذا البحث تم تقسيم مدينة أسيوط الجديدة إلى خمسين منطقة متساوية مساحة كل منها ٠.٣ كم٢ و أخذ عينة تربة من كل منها.

بعد تجميع هذه العينات تم طحنها إلى حجم ٢٠٠ ميكرومتر تقريبا ثم تم تسخينها إلى درجة ١١٠ درجة مئوية للتخلص من أي آثار للماء ، ثم و ضعت في علب بلاستيكية محكمة الغلق لمدة أكثر من شهر قبل القياس و ذلك للوصول للإتزان الإشعاعي بين الراديوم و نواتج تحلله.

و يمكن تلخيص نتائج البحث في الاتي:

- تركيز النويات المشعة طبيعيا (الراديوم-٢٢٦ و الثوريوم-٢٣٢ و البوتاسيوم-٤٠) في العينات محل الدراسة تتراوح من ٩.٠٢±١.١٢ إلى ٥١.٦٤±١.٠٩ بيكريل/كجم للراديوم-٢٢٦ و تتراوح من ٩.٦٩±٢.٨٧ إلى٣٢.٦٦±١.٩٣ بيكريل/كجم للثوريوم-٢٣٢ و تتراوح من ١٠٨.١٥±٠.٤١ إلى ٢٩٠.٧٣±٠.٢٨ بيكريل/كجم للبوتاسيوم-٤٠ .

- المخاطر الإشعاية الناتجة من التعرض لأشعة جاما
  - **المكافيء الراديومي:** قيم المكافيء الراديومي لكل العينات أقل من المتوسط العالمي و هو ٣٧٠ بيكريل/كجم .
  - **الجرعة الممتصة:** قيم الجرعة الممتصة لكل العينات أقل من المتوسط العالمي و هو ٧٥ نانوجراي / ساعة.
  - **معامل الخطر الإشعاعي الداخلي و الخارجي:** القيم المحسوبة لمعامل الخطر الإشعاعي الداخلي و الخارجي لكل العينات أقل من الواحد الصحيح ، اي أنها لا تمثل أي خطر إشعاعي
  - **متوسط الجرعة المكافئة السنوية:** قيم متوسط الجرعة المكافئة السنوية (داخل المنزل) لجميع العينات أقل من الحد المسموح به عالميا و هو ٤٥٠ ميكرو سيفرت/ سنة.

ويخلص هذا البحث إلى أن التربة في أسيوط الجديدة آمنة تماما من الناحية الإشعاعية و أن المخاطر الإشعاعية التي يتعرض لها السكان في الحدود الآمنة .