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Radioactivity and Radiological Hazard Effects for Granitic Gneisses at Wadi Abu Rushied Area, South Eastern Desert, Egypt.

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Abstract: *A three main types of measurements were performed in order to get a complete assignment for radioactivity impacts for the studied area,i) A ground gamma-ray spectrometric survey has been performed using a portable gamma-ray spectrometer model Rs-230., The gamma-ray spectrometric maps acquired indicate various concentrations of radioactivity over the studied area, which reflects a contrasting radioelement contents for the exposed rock. ii) The activity concentrations of naturally occurring radionuclides in the area under investigation, were determined using high pure germanium detector (HPGe) with a specially designed shield, in order to assess the radiological health hazards.Absorbed dose rate (D), radium equivalent (Ra_{eq}), external hazard index (H_{ex}), annual effective dose equivalent (AEDE), representative level index (I_{γ}), excess lifetime cancer risks (ELCR) and annual gonadal dose equivalent (AGDE) are calculated.The results were compared with the international recommended values, higher values for both activity concentrations and radiation indices were measured for the studied samples. iii) The activity ratios in the selected samples are calculated to clues for what happened in the studied rock. Groundwater circulation and Weathering, lead to different physico-chemical conditions affecting ^{238}U and ^{234}U will result in their fractionation and, thus, the respective activity ratios will therefore be greater or less than unity.*

Key words: *Granitic Gneisses/ Natural radioactivity/ Activity ratios/ Annual gonadal dose equivalent/ Excess life cancer risk.*

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I. Introduction

Abu Rushied area is located in the South Eastern Desert of Egypt (about 45 km southwest of Marsa Alam), between latitudes 24° 37′ 43"–24° 38′ 26" N and longitudes 34° 46′ 00" – 34°46′ 35" E. The main rocks in the studied area are the granitic gneisses, surrounded mafic-ultramafic rocks and granites. Uranium minerals, iron oxides, zincite, clay minerals, fluorite and manganese oxides are present as thin films along fractures planes in the studied area **[1]**. It is also dissected by the two main shear zones trended N-S and E-W direction. These shear zones are occupied by a mineralized and highly altered lamprophyre dyke **[2]**. Many alteration halos are observed, such as argillization, hematitization, silicification, greisenization, sericitization and fluoritization **[1]**. These types of alteration are associated with a wide variability in radioactivity with or without U- mineralization plays an important role in localizing uranium (U) and thorium (Th) mineralization.

In this case a significant component of the background radiation exposure to human beings are generating, depends on their contributing compositions values of total dose **[3]**. Natural radionuclides ^{238}U, ^{235}U and ^{232}Th may become incorporated in igneous materials when they are originally formed from the molten state **[4]**. Since these radionuclides are not uniformly distributed, the knowledge of their distribution in soil and rocks plays a vital role in radiation protection and measurement **[5]**.

The terrestrial background radiation levels are related to the types of rock from which the soils originate. Levels of higher radiation are associated with igneous rocks as granite and lower levels with mafic-ultramafic and sedimentary rocks. **[6]**.

II. Geologic setting

The studied rock is named as granitic gneiss,which occurs in the field down thrusted the ophiolitic mélange and foliated in ENE-WSW direction, it is occupying the core of that granitic pluton and cross cut by two shear zones. The studied area (500x1000 m) is characterized by low to moderate topography and highly tectonized rocks. (Fig. 1)show a grade 100 x 100m representing the collected sample.

The studied rock is light grey to grey in color, fine to coarse-grained and exhibit both gneissosity and characterized by absence of enclaves, it composed mainly of feldspar, quartz, mica and some accessory minerals.

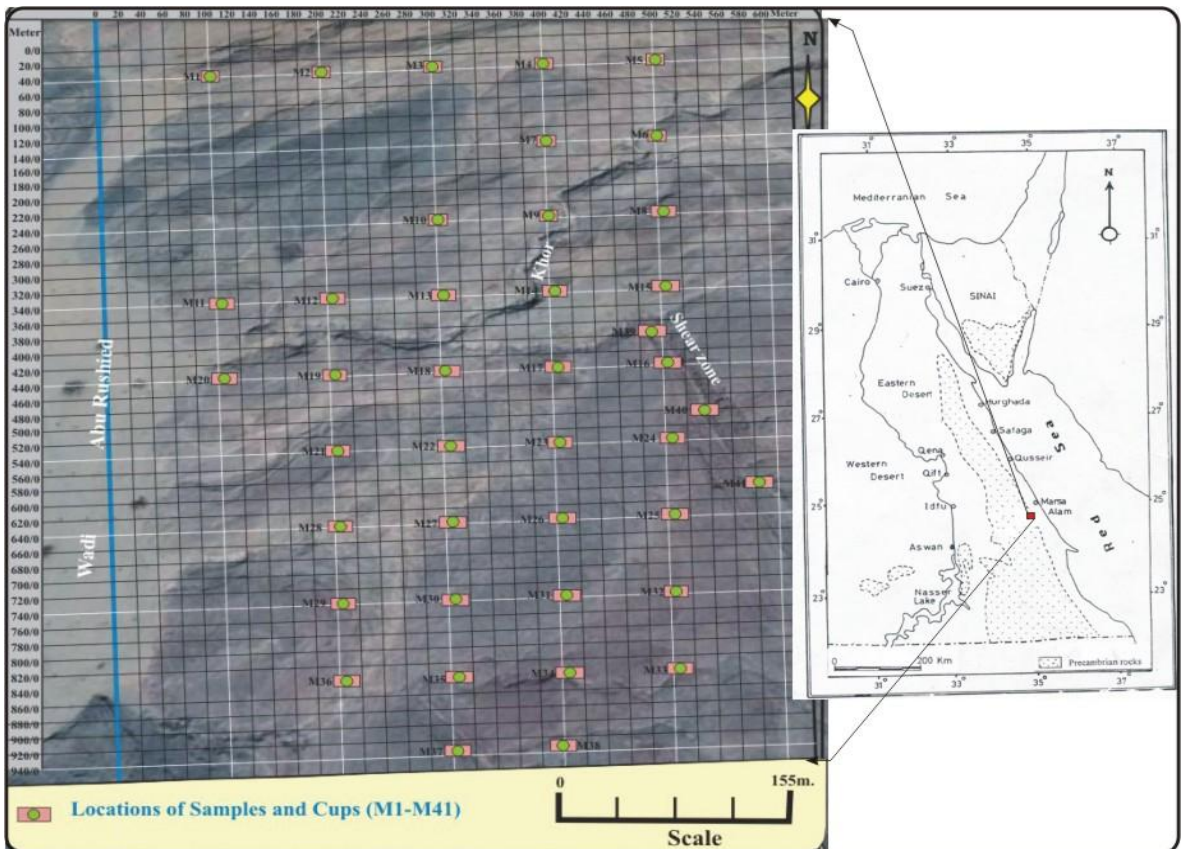


Fig. (1):Landsat map showing the location and net of samples in Abu Rushied area, South Eastern Desert.

III. Methodology

3.1. Field Workmeasurements

Ground spectrometric surveying using a portable gamma-ray spectrometer model Rs-230, was carried out over the studied area. The premised area was selected for the details study based on its high radioactivity and mineralization. Sampling were carried out each 100 m. A total of 41 points covered the study area and 41 rock samples were taken for radiometric and geochemical analysis as in (Fig. 1).

3.2. Lap measurements

Gamma-ray spectrometry is commonly used because it is a non-destructive method and in general does not require sample preparation. High-resolution gamma-ray spectrometry based on germanium detectors has been routinely applied in various fields of research and industry. It allows qualitative and quantitative analyses of radioactive materials**[7]**.

The collected samples from the studied area were numbered from M-1 to M-41, and prepared for $\gamma -ray$ spectrometric analyses using HPGe detector, then the studied samples were dried at room temperature for a week, crushed then sieved through (200) mesh size, the quartering technique was used to get a representative sample for each horizon. Weighted samples were placed in polyethylene containers of 200 cm^3 volume. The container was sealed hermetically and externally using cellphone tape and kept for about one month to allow radioactive equilibrium.

The efficiency calibration in this work was performed using threewell-known reference materials obtained from the International Atomic Energy Agency for U, Th and K activity measurements: RGU-1, RGTh-1 and RGK-1 **[8,9]**. The sample containers were placed on top of the detector for counting. The same geometry and size were used for both measured and reference materials samples **[9]**. The uranium reference material (RGU-1) is U-ore diluted with silica with 4940 Bq/kg of ^{238}U, 228 Bq/kg of ^{235}U, a negligible amount of ^{40}K (less than 0.63 Bq/kg) and some traces of ^{232}Th (lessthan 4 Bq/kg). The thorium reference material (RGTh-1) is Th-ore diluted with silica having 3250 Bq/kg of ^{232}Th, but containing some ^{238}U (78 Bq/kg) and ^{40}K (6.3 Bq/kg). The potassium calibration reference material (RGK-1) is produced from high purity (99.8%)potassium sulphate

with 14000 Bq/kg of potassium with uraniumand thorium contents lower than 0.001 and 0.01 ppm, respectively **[9,11].**

The radionuclide ^{238}U activity was determined indirectly from the gamma rays emitted by its daughter products (^{234}Th and ^{234m}Pa) which activities are determined from the 63.3 and 1001 keV, respectively **[12]**. The ^{234}U activity was determined directly from the gamma rays emitted from this nuclide at energies of 53.2 keV and 120.9 keV **[13-15]**. For the measurement of the ^{230}Th activity, the ɣ-ray emission at 67.7 keV is used **[16]**. The activity of ^{226}Ra was measured using the 186.1 keV from its own gamma-ray (after the subtraction of the 185.7 keV of ^{235}U). The specific activity of ^{214}Pb was measured using the 241.9, 295.2 and 351.9 keV while the specific activities of ^{214}Bi and ^{210}Pb were measured using 609.3 and 46.5 keV, respectively.The ^{235}U activity was determined directly by its gamma ray peaks; 143.8, 163.4, 185.7, and 205.3 keV **[15,17,18]**. The specific activity of ^{232}Th was measured using the 338.4 keV and 911.2 keV from ^{228}Ac and 583 keV and 2614.4 keV from ^{208}Tl. The specific activity of ^{40}K was measured directly by its own gamma-ray at1460.8 keV.

IV. Results And Discussion

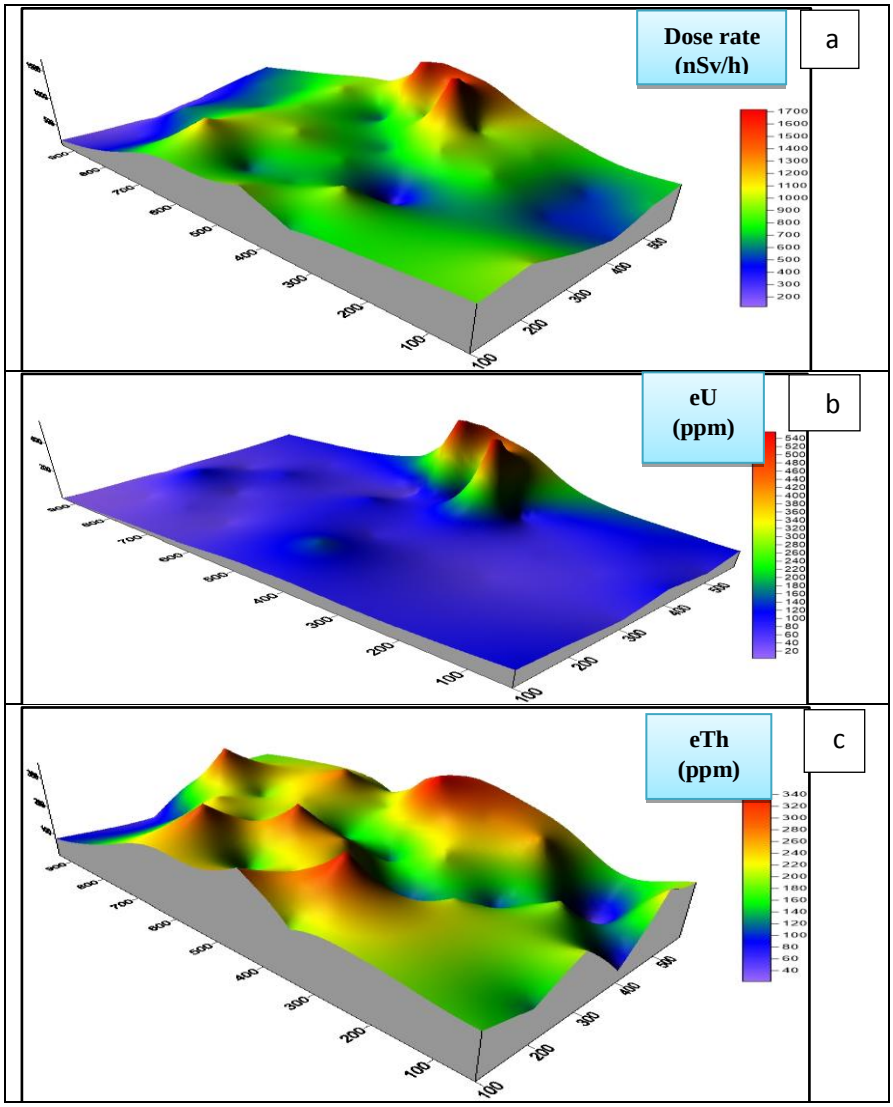
4.1 Ground measurements

Table (1) show the obtained results fordose rate, eU, eTh in ppm, K in %,and their ratios eU/eTh, eU/K and eTh/K, where the value of eU/eTh ratio is important for uranium exploration because it depends mainly on the mobility of uranium. Therefore, it outlines the most promising area of uranium migration and accumulation.
Fig. 2 (a, b, c& d) represents graphically the distributions of dose rate, eU, eTh, and K% respectivelyon the studied area.It shows that regular behavior for dose rate, and high values of eU and K% were noted at the northern part where the granitic rock is dominating. A nearly uniform distribution for eTh along the studied area with some highpeaks is found with absence of high concentration of K% is noted specially in the southern part.
Fig. (3a) illustrated the eU/eTh ratio, which indicates that there is high anomaly in the southern part of the studied area. Figure (3b) illustrated the eU/K ratio, which indicates high abnormality on the east sides of the studied area. Figure (3c) is showing the eTh/ K ratio, which represent uniform distribution along the studied area with some peaks of high concentration in the east part of the studied area. The resultant of the former figures isrevealedlevels ofdifferent radioactivity, which reverse contrasting radioelement contents for the exposed gneisses granite.

Table (1): The measured values for dose rate, eU, eTh, K, and their ratios by ground spectrometer Rs-230

Station	(D.R) ($nSvh^{-1}$)	eU (ppm)	eTh (ppm)	K%	eU/eTh	eU/k	eTh/k
40/100	880	110	170	4.1	0.65	26.8	41.5
40/200	980	90	130	4.0	0.69	22.5	32.5
40/300	700	59	210	3.9	0.28	15.1	53.8
40/400	500	107	60	3.5	1.78	30.6	17.1
40/500	690	69	240	3.2	0.29	21.6	75.0
140/500	500	100	18	1.5	5.56	66.7	12.0
140/400	490	58	202	3.0	0.29	19.3	67.3
240/500	870	85	260	3.3	0.33	25.8	78.8
240/400	850	59	100	3.5	0.59	16.9	28.6
240/300	620	40	210	3.00	0.19	13.3	70.0
340/100	670	80	189	3.8	0.42	21.1	49.7
340/200	1000	81	350	4.2	0.23	19.3	83.3
340/300	300	58	60	4.7	0.97	12.3	12.8
340/400	1000	83	220	3.0	0.38	27.7	73.3
340/500	970	87	270	5.2	0.32	16.7	51.9
440/500	890	45	360	5.4	0.13	8.3	66.7
440/400	650	90	120	5.0	0.75	18.0	24.0
440/300	750	65	260	4.5	0.25	14.4	57.8
440/200	700	150	219	4.8	0.68	31.3	45.6
440/100	1000	79	300	3.5	0.26	22.6	85.7
540/200	580	85	150	2.9	0.57	29.3	51.7
540/300	980	89	320	4.0	0.28	22.3	80.0
540/400	780	110	140	4.0	0.79	27.5	35.0
540/500	600	35	200	3.5	0.18	10.0	57.1
640/500	980	70	290	4.8	0.24	14.6	60.4
640/400	880	59	230	4.1	0.26	14.4	56.1
640/300	970	65	190	5.0	0.34	13.0	38.0
640/200	1200	30	320	4.0	0.09	7.5	80.0
740/200	540	50	180	2.5	0.28	20.0	72.0
740/300	720	40	240	4.0	0.17	10.0	60.0

740/400	610	95	185	3.3	0.51	28.8	56.1
740/500	700	60	230	3.0	0.26	20.0	76.7
840/500	600	65	210	3.9	0.31	16.7	53.8
840/400	500	40	320	3.8	0.13	10.5	84.2
840/300	590	125	115	5.2	1.09	24.0	22.1
840/200	300	18	110	3.7	0.16	4.9	29.7
940/300	120	16	55	2.5	0.29	6.4	22.0
940/400	250	40	150	3.8	0.27	10.5	39.5
400/520	1800	600	310	3.0	1.94	200.0	103.3
500/540	1700	580	300	2.0	1.93	290.0	150.0
600/560	1000	195	175	5.7	1.11	34.2	30.7
Range	**120-1800**	**16-600**	**18-360**	**1.5-5.7**	**0.09-5.56**	**4.86-290**	**12-150**
Average	**766.1**	**99.1**	**204.1**	**3.8**	**0.64**	**30.85**	**55.75**



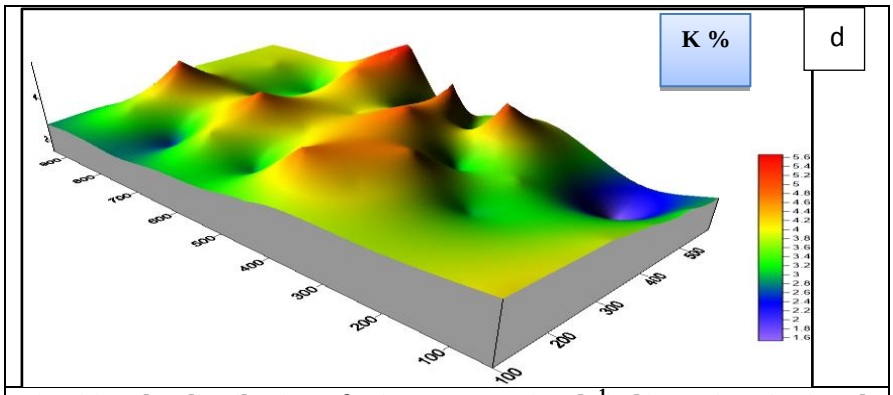


Fig. (2): The distribution of; a) Dose rate (nSvh^{-1}), b) eU (ppm), c) eTh (ppm), and d) K%

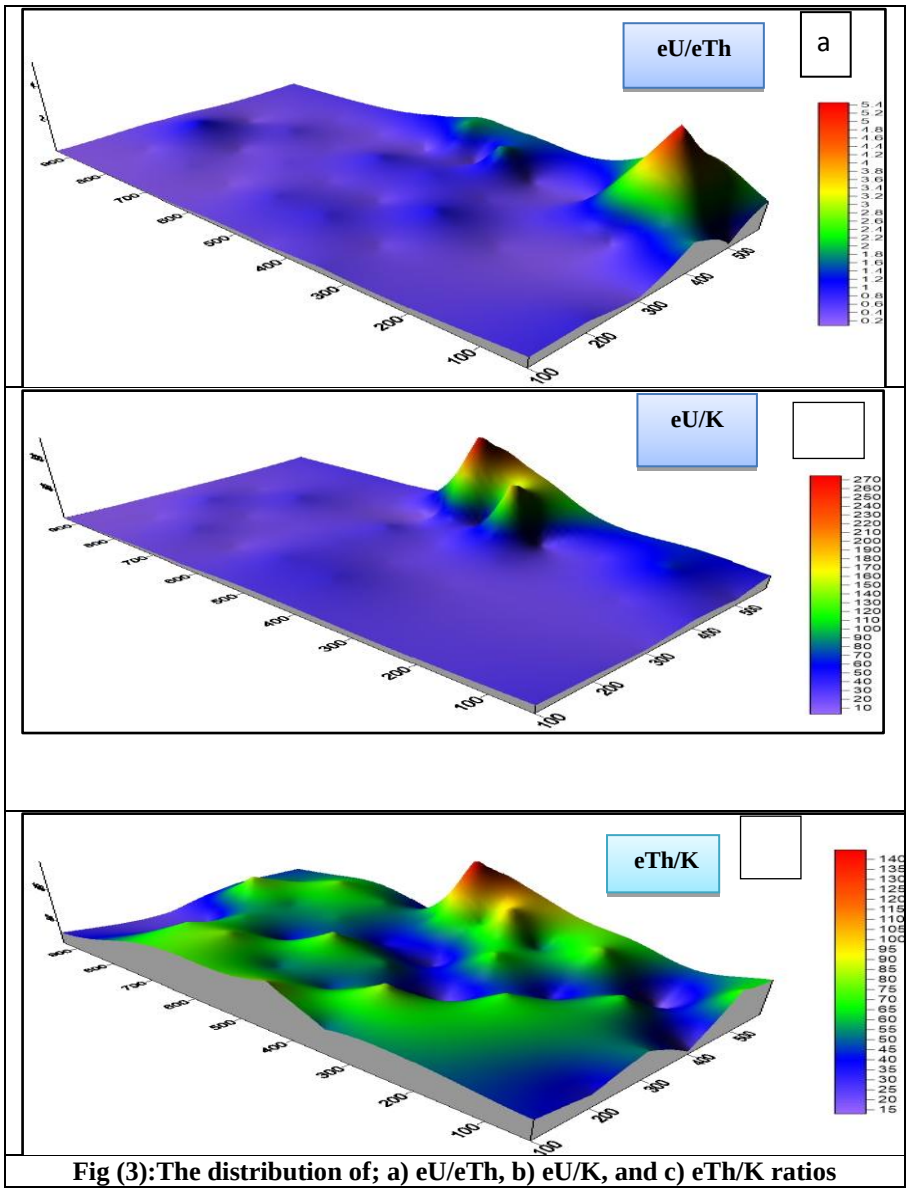


Fig (3):The distribution of; a) eU/eTh, b) eU/K, and c) eTh/K ratios

4.2. Radioactivity Concentration

The activity concentrations (Bq/kg) of different radionuclides (^{238}U, ^{226}Ra, ^{232}Th, ^{40}K,^{235}U, ^{234}U and^{230}Th) measured by HPGe in the studied samples are presented in table (2). The results indicate that; the activity concentrations of ^{238}U, ^{226}Ra, ^{232}Th, ^{40}K,^{235}U, ^{234}U and ^{230}Th ranged from 203.7 to 7574.64, 81.75 to 12438.44, 34.62 to 1439.88, 167.6 to 1771.35, 9.37 to 351.45, 190 to 8621.6 and from163.91 to 12045.99,

respectively. The highest values of activity concentrations of ^{238}U, ^{226}Ra and ^{40}K present in shear zone samples (M-39 and M-41), while the highest value of ^{232}Th present in sample (M-16). The highest activity concentration of ^{235}U present in samples (M-39).

The activity concentrations of $^{238}U$and ^{226}Ra for all the studied samples which are higher than the average of the world value of 33 and 32 Bq/kg, respectively **[19]**. But for ^{232}Th all the studied samples are higher than the average world 45 Bq/kg, except two samples (M-6) and (M-40). The activity concentrations of ^{40}K are more than the permissible level 413 Bq/kg **[19]**, except one sample (M-6).

The lowest valuesof^{234}U and ^{230}Th are in sample (M-37) is 190 and 163.91 Bq/kg, respectively, while the highest values are in sample (M-39) is 8621.6 and 12045.99 Bq/kg, respectively.

Table (2): Activity concentrations (Bq/kg) of ^{238}U, ^{226}Ra, ^{232}Th, ^{40}K, ^{235}U, ^{234}U and ^{230}Th in the studied samples.

Station	S. No.	^{238}U (Bq/kg)	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{40}K%	^{235}U (Bq/kg)	^{234}U (Bq/kg)	^{230}Th (Bq/kg)
40/100	**M-1**	1085.34	1335.51	468.72	1208.92	50.08	378.50	1004.96
40/200	**M-2**	1025.37	918.01	567.15	1073.22	47.18	390.45	828.97
40/300	**M-3**	918.13	688.68	818.69	979.82	42.56	488.52	834.71
40/400	**M-4**	1350.71	1169.47	230.88	977.93	62.16	1292.07	1318.13
40/500	**M-5**	815.12	721.51	1086.52	996.75	37.58	367.05	722.04
140/500	**M-6**	1233.61	1243.49	34.62	167.60	56.85	792.40	1166.84
140/400	**M-7**	772.24	484.48	788.04	842.25	35.70	531.13	586.10
240/500	**M-8**	873.12	878.19	1087.79	1016.41	40.23	572.91	732.31
240/400	**M-9**	814.79	775.50	982.48	1036.09	37.57	576.59	639.60
240/300	**M-10**	468.99	675.61	872.57	924.42	21.46	507.73	403.72
340/100	**M-11**	1035.37	1250.06	733.14	979.51	48.02	275.25	908.79
340/200	**M-12**	948.14	728.29	1399.34	1293.45	43.22	278.50	638.46
340/300	**M-13**	697.14	722.04	211.29	1388.66	31.99	873.88	590.84
340/400	**M-14**	1091.08	956.47	921.36	848.51	49.86	311.32	849.03
340/500	**M-15**	939.41	833.11	1113.66	1632.40	43.61	1117.38	980.50
440/500	**M-16**	556.92	609.36	1439.88	1615.19	25.57	551.52	610.35
440/400	**M-17**	940.33	916.08	485.23	1035.88	43.47	803.03	743.68
440/300	**M-18**	747.99	1003.25	1049.74	1351.91	34.61	433.80	706.58
440/200	**M-19**	1851.35	1981.02	904.19	1490.33	85.10	767.99	1718.30
440/100	**M-20**	957.17	1216.60	1199.61	1028.01	43.94	1128.61	857.34
540/200	**M-21**	1137.61	812.56	601.48	820.16	52.61	913.54	896.73
540/300	**M-22**	1086.50	701.30	1303.76	1191.36	50.30	249.07	901.34
540/400	**M-23**	1357.05	1493.70	565.18	1178.04	63.11	1343.50	1198.37
540/500	**M-24**	432.47	398.52	807.28	1054.96	20.03	340.99	306.78
640/500	**M-25**	930.06	971.76	1154.40	1489.99	42.88	671.96	680.45
640/400	**M-26**	744.67	882.82	941.55	1301.36	34.39	559.02	817.54
640/300	**M-27**	848.22	775.85	789.96	1569.03	39.37	1105.40	764.74
640/200	**M-28**	424.12	81.75	1310.34	1199.14	19.58	570.37	365.12
740/200	**M-29**	627.53	450.39	753.55	757.41	28.92	628.56	525.22
740/300	**M-30**	513.03	477.25	972.32	1213.57	23.50	418.20	539.57
740/400	**M-31**	1211.41	969.96	755.94	999.72	55.85	671.46	837.47
740/500	**M-32**	932.93	856.28	945.95	994.02	42.81	393.41	784.05
840/500	**M-33**	842.72	648.73	860.09	1152.59	39.06	860.38	572.10
840/400	**M-34**	506.62	346.85	1317.21	1163.08	23.43	347.62	415.17
840/300	**M-35**	1551.48	1455.45	478.74	1658.30	71.31	1342.74	1216.16
840/200	**M-36**	232.10	222.05	470.17	1139.47	10.65	316.31	171.89
940/300	**M-37**	203.70	193.01	232.40	730.87	9.37	190.00	163.91
940/400	**M-38**	550.79	612.68	634.85	1175.77	25.24	802.66	538.35
400/520	**M-39**	7574.64	12438.44	1250.67	949.78	351.45	8621.60	12045.99
500/540	**M-40**	7232.82	8663.94	120.01	479.23	336.09	4240.67	6118.38
600/560	**M-41**	2432.22	2950.17	724.90	1771.35	112.87	1224.23	2416.41
Range		**203.7-7574.6**	**81.75-12438.4**	**34.6-1439.8**	**167.6-1771.3**	**9.37-351.4**	**190-8621.6**	**163.9-12045.9**
Average		**1231.59**	**1353.9**	**814.2**	**1118.9**	**56.5**	**932.9**	**1190.8**

Table (3) shows the concentrations of ^{238}U, ^{232}Th in ppm and the ratio Th/U {calculated by divided the activity concentration by the specific activity}, considering 1ppm = 12.4 Bq/kg for^{238}U and 1ppm = 4.05 Bq/kg for ^{232}Th **[9]**.

In igneous rocks, Th/U ratio is about 3.5:1,this ratio depends on content of U (mobile element).So Th/U ratio is important for U exploration meanwhile the determination of U-rich zones. Consequently, in granites, U enrichment (leach in of U) can be indicated by low ratio (<3.5), while U depletion [leach out of U (mobilization) or initially U poor source is indicated by high ratio (>3.5)according to Clark value**[20]**. The

results show that, the Th/U ratio was ranged from 0.05 (M-40) to 9.46 (M-28), where the ratio Th/U of 20 samples greater than 3.5.

Table (3): Results of radionuclide concentrations for the studied samples

Station	S. No.	^{238}U (ppm)	^{232}Th (ppm)	Th/U
40/100	M-1	87.53	115.73	1.32
40/200	M-2	82.69	140.04	1.69
40/300	M-3	61.83	202.14	3.27
40/400	M-4	108.93	57.01	0.52
40/500	M-5	65.74	268.28	4.08
140/500	M-6	99.48	8.55	0.09
140/400	M-7	62.28	194.58	3.12
240/500	M-8	70.41	268.59	3.81
240/400	M-9	65.71	242.59	3.69
240/300	M-10	37.82	215.45	5.70
340/100	M-11	83.50	181.02	2.17
340/200	M-12	76.46	345.52	4.52
340/300	M-13	56.22	52.17	0.93
340/400	M-14	87.99	227.50	2.59
340/500	M-15	75.76	274.98	3.63
440/500	M-16	44.91	355.53	7.92
440/400	M-17	75.83	119.81	1.58
440/300	M-18	60.32	259.20	4.30
440/200	M-19	149.30	223.26	1.50
440/100	M-20	77.19	296.20	3.84
540/200	M-21	91.74	148.51	1.62
540/300	M-22	87.62	321.92	3.67
540/400	M-23	109.44	139.55	1.28
540/500	M-24	34.88	199.33	5.72
640/500	M-25	75.00	285.04	3.80
640/400	M-26	60.05	232.48	3.87
640/300	M-27	68.40	195.05	2.85
640/200	M-28	34.20	323.54	9.46
740/200	M-29	50.61	186.06	3.68
740/300	M-30	41.37	240.08	5.80
740/400	M-31	97.69	186.65	1.91
740/500	M-32	61.43	233.57	3.80
840/500	M-33	67.96	212.37	3.12
840/400	M-34	40.86	325.24	7.96
840/300	M-35	125.12	118.21	0.94
840/200	M-36	18.72	116.09	6.20
940/300	M-37	16.43	57.38	3.49
940/400	M-38	44.42	156.75	3.53
400/520	M-39	610.86	308.81	0.51
500/540	M-40	583.29	29.63	0.05
600/560	M-41	196.15	178.99	0.91

4.3. Measurements of Activity Ratios

If the ratio of daughter/parent activity in the decay series are not equal to unity, then the radionuclides have been disturbed, possibly by groundwater transport of radionuclides into or away from the rocks.Observing of a $^{234}U/^{238}U$ ratio that is less or greater than unity clearly shows that an isotope of U has migrated inside the rock during the last 1–2 Ma. Other daughter/parent activity ratios can be used to detect radionuclide migration over shorter time-scales, such as $^{230}Th/^{234}U$ (350 ka) and $^{226}Ra/^{230}Th$ (8 ka) **[21]**.

The nuclides of^{238}U, ^{234}U and^{230}Th in closed geological systemsattain radioactive equilibrium after 1.7 Ma, i.e., respective activity ratios $^{234}U/^{238}U$, $^{230}Th/^{234}U$ and $^{230}Th/^{238}U$ all equal unity. If the systems are exposed to weathering and groundwater circulation, the different physico-chemical conditions affecting U^{238} and U^{234} will result in their fractionation and, thus, the respective activity ratios will therefore be greater or less than unity.

Briefly, two forms of mechanisms produce variations in the U-series nuclides;the first is when chemical processes which disturbs parent and daughter element pairs (e.g., dissolution, adsorption, precipitation), andthe second is physical process (the α-recoil effect) as in fig (4).

When a particle is ejected, the daughter nuclide recoils in the opposite direction and moves within the host mineral. Because it can be ejected from the host mineral or because its crystallographic site is damaged, the parent daughter is more easily mobilized **[22].**

While^{234}U and ^{238}U have comparable chemical conductand therefore should not be fractionated by chemical weathering of minerals, several authors have shown that this assumption is not verified in nature. The reason why^{234} $U/^{238}U$ activity ratios of weathered solids are smaller than unity is known as the α-recoil effect

and is explained by the preferential leaching of ^{234}U from *α* -recoil-damaged lattice sites in minerals. In contrast, ^{238}U enriches the strong phase**[22].**

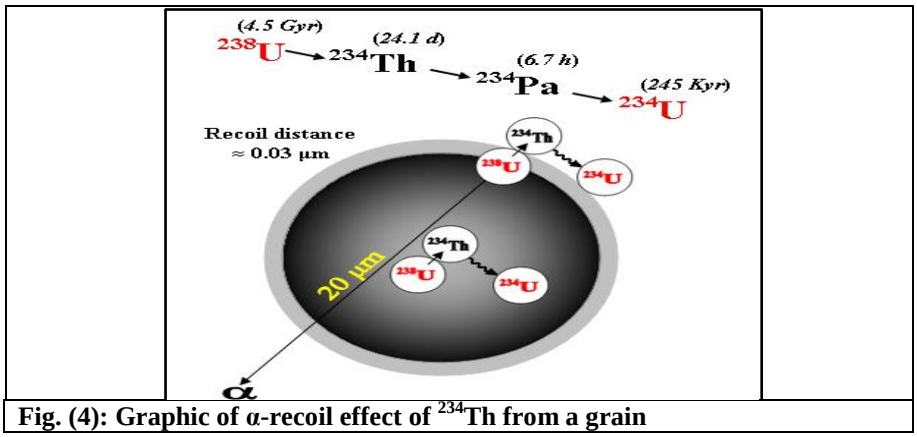


Fig. (4): Graphic of α-recoil effect of ^{234}Th from a grain

Table (4) shows the activity ratios$^{238}U/^{235}U$, $^{234}U/^{238}U$, $^{226}Ra/^{238}U$, $^{226}Ra/^{230Th}$, $^{230}Th/^{238}U$, $^{230}Th/^{234}U$ and $^{234}U/^{235}U$ for the studied samples which reflect what happened in the rocks.

The activity ratio of $^{238}U/^{235}U$ for samples ranged from (21.5 - 21.94) which reflectsa slight deviation from the natural ratio 21.7 and the alteration process did not change this ratio as shown in fig (5).

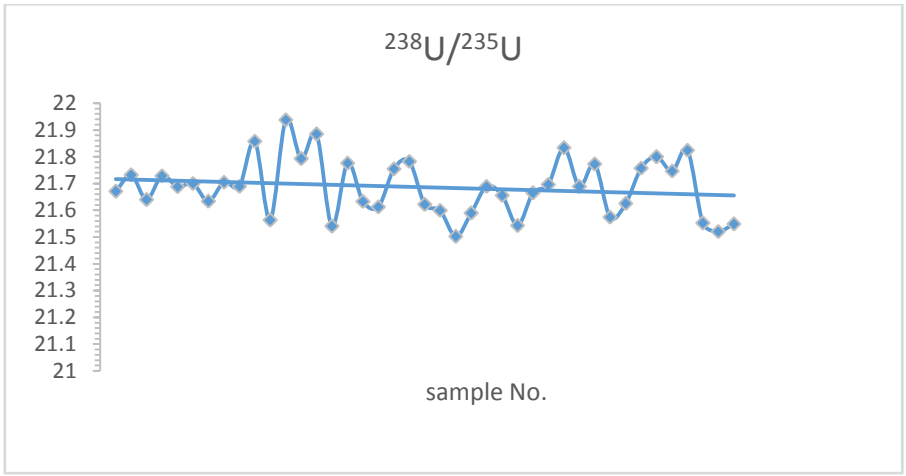


Fig (5): Variation of the ^{238}U /^{235}U activity ratio

The activity ratio of $^{234}U/^{238}U$ for the studied samples range between (0.19-1.46). Because of the α-recoil process and preferential leaching of ^{234}U relative to ^{238}U, the activity ratio of ($^{234}U/^{238}U$) for the studied samples are lower than unity except eight samples.

The activity ratios of $^{226}Ra/^{238}U$ and $^{226}Ra/^{230}Th$ range between (0.19-1.64) and (0.22- 1.67), respectively. The $^{226}Ra/^{238}U$ activity ratios < 1 in 13 samples which indicate the accumulation of uranium while in 11 samples are greater than unity indicating the uranium leaching out.

The removal of uranium from granitic rocks is generally characterized by $^{234}U/^{238}U \leq 1$ and $^{230}Th/^{234}U>$**1 [23,24]** which is similar to the most studied samples.
The main reason for these ratios is that groundwater leaches ^{234}Upreferentially to ^{238}U and removes both uranium isotopes relative to ^{230}Th.

This phenomenon may have occurredfor the granitic rocks from the area ofstudy, whereas the ratio$^{234}U/^{238}U > 1$ in eight samples and $^{230}Th/^{234}U < 1$ in fifteen samples.
The activity ratios of $^{230}Th/^{238}U$ for the studied samples ranges between (0.76-1.59).

The $^{234}U/^{235}U$ ratio in the studied samples range between (4.14-31.8), which indicates thaturanium is leaches from most samples due to alteration processes.

Table (4) Activity ratios of radionuclides for the studied samples

Station	S.No.	$^{238}U/^{235}U$	$^{234}U/^{238}U$	$^{226}Ra/^{238}U$	$^{226}Ra/^{230}Th$	$^{230}Th/^{238}U$	$^{230}Th/^{234}U$	$^{234}U/^{235}U$
40/100	**M-1**	21.67	0.35	1.23	1.33	0.93	2.66	7.56
40/200	**M-2**	21.73	0.19	0.90	1.11	0.81	2.12	4.14
40/300	**M-3**	21.57	0.54	1.23	1.42	0.87	1.36	11.72
40/400	**M-4**	21.73	0.87	0.87	0.89	0.98	1.02	20.79
40/500	**M-5**	21.69	0.45	0.89	1.00	0.89	1.97	9.77
140/500	**M-6**	21.70	0.64	1.01	1.07	0.95	1.47	13.94
140/400	**M-7**	21.63	0.69	0.63	0.83	0.76	1.10	14.88
240/500	**M-8**	21.70	0.66	1.01	1.20	0.84	1.28	14.24
240/400	**M-9**	21.69	0.71	0.95	1.21	0.78	1.11	15.35
240/300	**M-10**	21.86	1.08	1.44	1.67	0.86	0.80	23.66
340/100	**M-11**	21.56	0.27	1.21	1.38	0.88	3.30	5.73
340/200	**M-12**	21.94	0.29	0.77	1.14	0.67	2.29	6.44
340/300	**M-13**	21.79	1.25	1.04	1.22	0.85	0.68	27.32
340/400	**M-14**	21.88	0.29	0.88	1.13	0.78	1.00	6.24
340/500	**M-15**	21.54	1.19	0.89	0.85	1.04	0.88	25.62
440/500	**M-16**	21.78	0.99	1.09	1.00	1.10	1.11	21.57
440/400	**M-17**	21.63	0.85	0.97	1.23	0.79	0.93	18.47
440/300	**M-18**	21.61	0.58	1.34	1.42	0.94	1.63	12.53
440/200	**M-19**	21.76	0.41	1.07	1.15	0.93	2.24	9.02
440/100	**M-20**	21.78	1.18	1.27	1.42	0.90	0.76	25.68
540/200	**M-21**	21.62	0.80	0.71	0.91	0.79	0.98	17.36
540/300	**M-22**	21.60	0.23	0.65	0.78	0.83	3.62	4.95
540/400	**M-23**	21.50	0.99	1.10	1.25	0.88	0.89	21.29
540/500	**M-24**	21.59	0.79	0.92	1.30	0.71	0.90	17.02
640/500	**M-25**	21.69	0.72	1.04	1.43	0.73	1.01	15.67
640/400	**M-26**	21.66	0.75	1.19	1.08	1.10	1.46	16.26
640/300	**M-27**	21.54	1.30	0.91	1.01	0.90	0.69	28.07
640/200	**M-28**	21.66	1.34	0.19	0.22	0.86	0.64	29.14
740/200	**M-29**	21.70	1.00	0.72	0.86	0.84	0.84	21.73
740/300	**M-30**	21.83	0.82	0.93	0.88	1.05	1.29	17.80
740/400	**M-31**	21.69	0.55	0.80	1.16	0.69	1.25	12.02
740/500	**M-32**	21.77	0.52	1.29	1.48	0.87	1.68	11.25
840/500	**M-33**	21.57	1.02	0.77	1.13	0.68	0.66	22.03
840/400	**M-34**	21.63	0.69	0.68	0.84	0.82	1.19	14.84
840/300	**M-35**	21.76	0.87	0.94	1.20	0.78	1.05	18.83
840/200	**M-36**	21.80	1.36	0.96	1.29	0.74	0.54	29.71
940/300	**M-37**	21.75	0.93	0.95	1.18	0.80	0.86	20.30
940/400	**M-38**	21.82	1.46	1.11	1.14	0.98	0.67	31.80
400/520	**M-39**	21.55	1.14	1.64	1.03	1.59	1.40	24.53
500/540	**M-40**	21.52	0.59	1.20	1.42	0.85	1.44	12.62
600/560	**M-41**	21.55	0.50	1.21	1.22	0.99	1.97	10.85
Range		**21.5-21.94**	**0.19-1.46**	**0.19-1.64**	**0.22-1.67**	**0.76-1.59**	**0.54-3.3**	**4.14-31.8**

4.4. Radiological Hazards Assessment

To be able to evaluate the radiation hazard indices factors, the concentrations of natural radionuclides in the studied rocks were measured.

a. Outdoor Absorbed Dose Rate (D_{out})

The D_{out} at 1m above the surface of theground is evaluated from the γ-radiation originating from ^{226}Ra, ^{232}Th and ^{40}K assuming anundistributed state of for U, Ra, Th and K. The absorbed dose rate could be achieved using the followingformula(D_{out}) **[25].**

$$\boldsymbol{D_{out}(nGy.h^{-1}) = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_K} \qquad (\mathbf{1})$$

Where D_{out} is the absorbed dose rate in ($nGy.h^{-1}$), A_{Ra}, A_{Th} and A_K are the concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively. The outdoor external doses must be less than the world's average of 59 $nGyh^{-1}$**[19]**.

b. Annual Effective Dose Equivalent $(AEDE)_{out}$

The annual outdoor effective dose equivalent $(AEDE)_{out}$ is estimated from the outdoor external dose rate (D_{out}), which can be calculated using the following equation **[19]**.

$$\boldsymbol{AEDE(\mu Sv.y^{-1}) = D(nGy.h^{-1}) \times 8760\ h \times 0.2 \times 1.7\ Sv.Gy^{-1}} \qquad (2)$$

where 8760h is the average annual time duration for exposure to radiation, 0.7 Sv. Gy^{-1} is the dose conversion factor; outdoor occupancy factor is 0.2.

c. Excess Lifetime Cancer Risk (ELCR)

Excess lifetime cancer risk (ELCR) was calculated using the following equation, depending on the calculated values of annual effective dose.

$$\boldsymbol{ELCR_{out} = AEDE_{out} \times LE \times RF} \qquad (3)$$

Where, $AEDE_{out}$ is the outdoor annual Effective Dose Equivalent, DL is average Duration of Life (estimated to be 70 years), and RF is the Risk Factor (Sv^{-1}), i.e. fatal cancer risk per Sievert. For stochastic effects, **[25]** uses RF as 0.05 for the public **[27].**

d. Annual Gonadal Dose Equivalent(AGDE)

Annual gonadal equivalent dose (AGED) is a measure of risk to sensitive cells from exposure to a specific amount of radiation. These sensitive cells include the gonadal, the bone marrow and surface cells. The following formula is used to calculate theannual gonadal equivalent dose **[28]**.

$$\boldsymbol{AGDE = 3.09\ A_{Ra} + 4.18\ A_{Th} + 0.314\ A_K} \qquad (4)$$

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

e. Radium Equivalent (Ra_{eq})

Owing to a non-uniform distribution of natural radionuclides in the soil samples, the real amount of activity of ^{226}Ra, ^{232}Th and ^{40}K in the samples can be assessedusing a common radiological index called the radium equivalent activity (Ra_{eq}). It is the most commonly used radiation hazardsassessmentindex. This estimates that 370 Bq.kg^{-1} of ^{226}Ra, 259 Bq.kg^{-1} of ^{232}Th and 4810 Bq.kg^{-1} of ^{40}K produce the same gamma-ray dose rate. Therefore, Ra_{eq} can be obtained by the following relation **[29].**

$$\boldsymbol{Ra_{eq}\ (Bq.kg^{-1}) = A_{Ra} + 1.43A_{Th} + 0.077A_K} (5)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bk/kg respectively**[19]**.

f. External Hazard Indices (H_{ex})

The existence of natural radionuclides causes the emission of γ ray in the environment. The external hazard index (H_{ex}) is used in order to estimate the biological hazard of the natural gamma radiation and it is given by this equation **[30].**

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \qquad (6)$$

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

g. Representative Level Index (I_γ)

This index can be used to estimate the level of γ – radiation hazard associated with the natural radionuclides. The representative level index radiation may be described as **[30]**.

$$\boldsymbol{I_\gamma = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_k}{1500}} (7)$$

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

Table (5) shows the results of radiological hazardswhich are calculated for the studied samples using equations(1-7).The ranges of the absorbed dose rates are (260-6541.6) $nGyh^{-1}$, and annual effective doses equvilent (outdoor) are(0.32-8.02) $mSvy^{-1}$. These values represent the lowest and highest values in the samples (M-37) and (M-39).The results of absorbed dose rate (D) and annual effective gamma dose (AEDE) are higher

than the internationally recommended values, and the highest values present in the sample (M-39) which are 6541.6 and 8.02,respectively. The results of the studied samples are higher than the world average of absorbed dose rate (D) and Annual effective **[19,31]**. Also the values of (ELCR) were varied from 1.12 to 28.08, which is greater than the recommended limit $0.29x10^{-3}$. Annual gonadal dose equivalent is calculated which ranged from 1797.34 (M-37) to 43960.81(M- 39) mSv/y. The results of the studied samples are higher than the world average of annual gonadal equivalent dose which is 300mSv/y.

Table (5) also gives the radium equivalent (Ra_{eq}) in Bq/kg, external hazard index (H_{ex}), radioactivity level index (I_{γ}), which ranged from 582 to 14300, 1.57 to 38.64 and from 4.1 to 96.06 respectively.
The Ra_{eq} (Bq/kg), which is higher than the recommended limit 370 Bq/kg **[18].** For H_{ex} and I_{γ},the lowest calculated values are present in sample (M-37), which are 1.57 and 4.1, respectively.

The highest calculated values are present in sample(M-39) which are 38.64 and 96.06 respectively. All the studied samples are higher than unity **[19]**.

Table (5): Absorbed dose rate (D), Annual Effective Dose Equivalent (AEDE) (out), ELCR, AGDE, Ra_{eq}, H_{ex} and I_{γ} for the studied samples.

Station	S. No.	D ($nGyh^{-1}$)	AEDE(out) ($mSvy^{-1}$)	ELCR	AGDE ($mSvy^{-1}$)	Ra_{eq} Bq/kg	H_{ex}	I_{γ}
40/100	M-1	950.5	1.17	4.08	6465.58	2099	5.67	14.40
40/200	M-2	811.4	1.00	3.48	5544.32	1812	4.89	12.51
40/300	M-3	853.52	1.05	4.17	5857.80	2188	5.91	15.12
40/400	M-4	720.5	0.88	3.09	4885.80	1575	4.26	10.76
40/500	M-5	1031.2	1.26	4.43	7084.11	2352	6.35	16.34
140/500	M-6	602.4	0.74	2.59	4039.71	1306	3.53	8.75
140/400	M-7	734.9	0.90	3.15	5055.54	1676	4.53	11.67
240/500	M-8	1105.1	1.36	4.74	7579.70	2512	6.78	17.41
240/400	M-9	994.9	1.22	4.27	6828.37	2260	6.10	15.69
240/300	M-10	877.7	1.08	3.77	6025.25	1995	5.39	13.85
340/100	M-11	1061.2	1.30	4.56	7234.76	2374	6.41	16.32
340/200	M-12	1235.6	1.52	5.30	8505.79	2829	7.64	19.71
340/300	M-13	519.1	0.64	2.23	3550.34	1131	3.06	7.85
340/400	M-14	1033.8	1.27	4.44	7073.19	2339	6.32	16.16
340/500	M-15	1125.6	1.38	4.83	7741.97	2551	6.89	17.78
440/500	M-16	1218.6	1.49	5.23	8408.78	2793	7.54	19.54
440/400	M-17	759.5	0.93	3.26	5184.21	1690	4.56	11.65
440/300	M-18	1153.9	1.42	4.95	7912.46	2608	7.05	18.09
440/200	M-19	1523.5	1.87	6.54	10368.85	3389	9.16	23.24
440/100	M-20	1329.5	1.63	5.71	9096.44	3011	8.13	20.79
540/200	M-21	772.9	0.95	3.32	5282.51	1736	4.69	11.98
540/300	M-22	1161.1	1.42	4.98	7990.81	2657	7.18	18.51
540/400	M-23	1080.6	1.33	4.64	7347.87	2393	6.46	16.40
540/500	M-24	715.7	0.88	3.07	4937.14	1634	4.41	11.43
640/500	M-25	1208.3	1.48	5.19	8295.99	2737	7.39	19.02
640/400	M-26	1030.8	1.26	4.42	7072.22	2329	6.29	16.17
640/300	M-27	901.0	1.10	3.87	6192.11	2026	5.47	14.12
640/200	M-28	879.2	1.08	3.77	6106.37	2048	5.53	14.45
740/200	M-29	694.8	0.85	2.98	4779.38	1586	4.28	11.04
740/300	M-30	858.4	1.05	3.68	5920.08	1961	5.30	13.71
740/400	M-31	946.4	1.16	4.06	6470.94	2128	5.75	14.69
740/500	M-32	1065.0	1.31	4.57	6912.08	2408	6.50	16.65
840/500	M-33	867.3	1.06	3.72	5961.66	1967	5.31	13.69
840/400	M-34	1004.3	1.23	4.31	6942.89	2320	6.26	16.26
840/300	M-35	1030.7	1.26	4.42	7019.21	2268	6.13	15.60
840/200	M-36	434.1	0.53	1.86	3009.23	982	2.65	6.94
940/300	M-37	260.0	0.32	1.12	1797.34	582	1.57	4.10
940/400	M-38	715.5	0.88	3.07	4916.04	1611	4.35	11.22
400/520	M-39	6541.6	8.02	28.08	43960.81	14300	38.64	96.06
500/540	M-40	4095.2	5.02	17.58	27423.70	8872	23.98	59.28
600/560	M-41	1874.7	2.30	8.05	12702.30	4123	11.14	28.10
Range		**260-6541.6**	**0.32-8.02**	**1.12-28.08**	**1797.34-43960.81**	**582-14300**	**1.57-38.64**	**4.10-96.06**

These results reflect a seriousenvironmentimpacts and harmful effects to the human health which needs a great care in handling with.

V. Conclusion

In order to outline the radioactive areas as suggested, the ground gamma ray spectrometric study was performed along the study area.The area under investigation contains gneisses granite, with high uranium, thorium and potassium concentrations.

The resultant image maps indicate distinct concentrationsof radiation, soreverse contrasting radioelement contents for the exposed rock in the studied area. The results show that, the values of Th/U ratio ranged from 0.05 (M-40) to 9.46 (M-28), where the ratio Th/U of 20 samples greater than 3.5.

The absorbed dose rate (D) and annual effective gamma dose (AEDE) are higher than the internationally recommended values, which are 59 $nGyh^{-1}$ and 0.07 $mSvy^{-1}$.

The values of (ELCR) were varied from 1.12 to 28.08, which is greater than the recommended limit $0.29x10^{-3}$.Annual gonadal dose equivalent is ranged from 1797.34 (sample M-37) to 43960.81 (sample 39) mSv/y.

The results of the studied samples are higher than the world average of annual gonadal dose equivalent which is 300 mSv/y.

Disequilibrium of the uranium series can potentially provide an important tool for tracing migration of uranium series radionuclides from different aquifer conditions. Because of the obtained results, precautions must be taken against elevated radioactivity for individuals working in this regionand also this kind of granite is not suitable for building materials. The information acquired in this research are reference values that should be used as a database row to draw a very significant radiological map of these areas.

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