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Environmental Impacts due to Natural Radioactivity of Mir Area Northwest Assuit City, Egypt

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Abstract: Natural radioactivity concentration due to ^{238}U, ^{232}Th and ^{40}K in two different regions in Mir area, Assuit Egypt was calculated. Samples were directly measured by *a high resolution gamma spectrometer* (HPGe detector). The average concentration of ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K for region A were found to be 29.13, 3.73, 24.90 and 23.28 Bq/kg, respectively. While in region B, the average concentrations were 19.94, 4.10, 17.01 and 15.96 Bq/kg, respectively. Environmental radiation hazard indices were estimated. The average of radium equivalent activity (Ra_{eq}) was 31.94 Bq/kg for region A and 24.1 for B region. The Average of external hazard index (H_{ex}) was 0.09 for region A and 0.065 for B region. Internal hazard index (H_{in}) was 0.15 for region A and 0.111 for region B. Gamma activity concentration index (Iγ) was 0.11 for region A and 0.165 for region B. Annual effective dose rate (AEDR) was 0.02 for region A and 0.014 for region B. This was based on the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K radionuclides. Results show that the environmental radiological hazard indices were less than the world permissible value. It could be concluded that, the study area is safe for the population, agricultural and any other purposes.

Key words: Natural radioactivity · Environmental impacts · Sedimentary rocks · Mir area · Egypt

INTRODUCTION

Rocks and soil consist of radionuclide in varying concentrations depending on the local geological and geophysical conditions [1]. ^{238}U, ^{232}Th with their daughter products and ^{40}K are main sources of natural radiations. The study of the concentrations and distributions of the natural radionuclides in rocks and soil allows understanding the radiological implication of these elements due to the gamma ray exposure of the body and irradiation of lung tissue from inhalation of radon and its daughters [2, 3, 4]. The excess exposure to the ionizing radiations emitted from the radioactive material may cause some health and environmental problems. It is therefore important to measure the concentration of radionuclides in rocks. The objective of this study is to determine the ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K radionuclide concentrations in some sedimentary rock of Mir area Assuit Egypt. The radiological hazard indices and environmental impact were estimated and discussed.

Geological Outline: Mir area is located north west of Assuit city and confined between Latitudes 27° 12\ 30\\ -- 27° 27\ 30\\ N and Longitudes 30° 40\ -- 30° 55\ E (Fig.1). This area has essentially a plain topography devoid of outcrops in most cases. The plain is covered by different Quaternary deposits (e.g. gravels, sand, silts and clay). Generally, the rock exposures bordering the west part of Nile valley including the present area were studied by some authors [5, 6].

Sampling and Methodology

Sampling and Sample Preparation: A total of forty two representative samples were collected from the Eocene limestone plateau of Mir area. The collected samples were taken from two main regions, referred as A (14 samples) and B (28 samples). These regions are located to the west and east of a road of about 3 km length. Region A is predominated by sedimentary rocks whereas region B is characterized by the presence of different types of organisms like bees, algae in addition to

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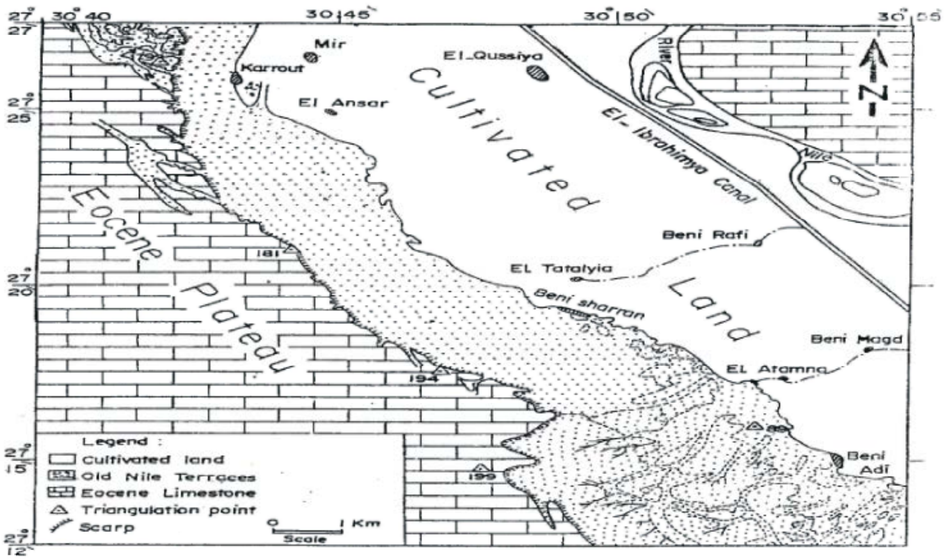

Fig. 1: Mir area map

faulted sedimentary rocks. The collected samples were crushed to grain size about 100 mesh. About 100 cc for each sample was weighted and packed in plastic containers, sealed well and stored for about 30 days before counting in order to allow the in growth of uranium and thorium decay products, prevent the escape of radiogenic gases ^{222}Rn and ^{220}Rn and to allow the attainment of equilibrium for ^{238}U and ^{232}Th with their respective progeny [7, 8]. After attainment of secular equilibrium, the samples were measured radio metrically using gamma spectrometer.

Natural Radiation Measurement: Activity concentration due to natural radionuclides, (^{238}U, ^{232}Th, ^{226}Ra and ^{40}K), were measured using energy and efficiency calibrated hyper pure germanium detector HPGe. The HPGe crystal diameter is 49.3 mm and its length is 47.1 mm with 15 % relative efficiency. The peak to Compton ratio is 52 and the resolution (FWHM) is 2 keV for 1.33 MeV gamma ray transition of ^{60}Co. Energy- efficiency calibration curve was done by using different standard sources ^{241}Am, ^{226}Ra, ^{133}Ba ^{137}Cs and ^{60}Co, which were putting in the same geometry beaker. An empty beaker with the same geometry was measured to subtract the background Gamma spectrum for each sample was accumulated for about 24 hours. For ^{238}U, ^{232}Th series and ^{40}K, the gamma energies which were taken to determine the concentrations of the assigned nuclides are shown in (Table 1). The spectra were analyzed with the computer software programming Maestro (EG&G ORTEC). The activity concentrations of the U, Th and K were measured in Bq/kg for the different gamma transitions [9, 10].

Table 1: Energies and branching ratio of U-238, Th -232 and K-40

	Uranium-238 series	
Nuclide	Energy (keV)	Photons per disintegration (%)
Th-234	63.3	3.8
Pa-232m	1001	0.7
Ra-226	186.1	3.3
Pb214	295.1	19.2
	352.1	37.1
Bi-214	609.3	46.1
	768.4	5.1
	934.1	3.2
	1120.3	15.1
	1238	5.9
	1378	4.0
	1729	3.1
	1765	15.9
	1847	2.1
	2204	5.0
	Thorium-232series	
Nuclide	Energy (keV)	Photons per disintegration (%)
Ac-228	209.4	4.1
	338.4	12.4
	462.1	4.6
	911.2	29.1
	966.6	23.2
BI-212	727.3	6.7
	1620	1.5
Tl-208	583.1	30.9
	860	4.3
	2614	35.8
	Potassium	
K-40	1460	10.74

Estimation of Environmental Hazard Indices: The activity levels of natural radiations have been represented by a single quantity Bq/kg to estimate the radio-environmental impacts; [11, 12, 13]. Among several radionuclides, ^{226}Ra is the most common and the most important one in the majority of the published papers concerned with the environmental radiation studies [14]. This is attributed to the fact that the external exposure to the population is mostly by gamma rays emitted from two main daughters of radium, namely ^{214}Pb and ^{214}Bi. About 98.5% of the radiological effects of the ^{238}U series are produced by radium and its daughters. Therefore, any disequilibrium between ^{238}U and ^{226}Ra has no effect on the dose estimation from the measurement of ^{226}Ra and the dose rates derived from ^{226}Ra are usually presented as that of ^{238}U [15].

In the present study, the radium equivalent activity (Ra_{eq}), external hazard index (H_{ex}) internal hazard index (H_{in}), gamma activity concentration index ($I\gamma$) and annual effective dose rate (AEDR) were estimated as environmental radiation hazard indices. This was based on the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K radionuclides.

The radium equivalent activity (Ra_{eq}) is the weighted sum of activities of ^{226}Ra, ^{232}Th and ^{40}K based on the presumption that 10 Bq/kg of ^{226}Ra, 7 Bq/kg of ^{232}Th and 130 Bq/kg of ^{40}K produce the same gamma-ray dose rates, [16, 17]. It is defined as :

$$Ra_{eq} = A_{Ra} + 1.43\ A_{Th} + 0.077\ A_K \quad (1)$$

here $A_{Ra,}$ A_{Th} and A_K are activities (Bq/Kg) of ^{226}Ra, ^{232}Th and ^{40}K, respectively. The maximum value of this index must be < 370 Bq/Kg [for keeping the external dose < 1.5 m Gy y^{-1}].

The radium equivalent activity was modified by other quantity index named as the external hazard index. This index measures the external hazard due to γ - radiation and was defined as:

$$H_{ex} = 0.0027A_{Ra} + 0.0039\ A_{Th} + 0.00021\ A_K = 1 \quad (2)$$

The value of this index must be lower than unity in order to keep the radiation hazard insignificant. The maximum value of unity for this index corresponds to the limit of 370 Bq/kg for Ra_{eq}. In addition to the external irradiation, radon and its short-lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter products is quantified by the internal hazard index (H_{in}). It is given by the following equation.

$$H_{in} = 0.0054A_{Ra} + 0.0039A_{Th} + 0.00021\ A_K = 1 \quad (3)$$

The value of this index must be lower than unity in order to keep the radiation hazard insignificant.

Radioactivity level index (I_γ) is used to estimate the level of radiation risk, especially γ rays, associated with the natural radionuclides in specific materials. It is defined as:

$$I_\gamma = 0.0033A_{Ra} + 0.005A_{Th} + 0.00033A_K = 1 \quad (4)$$

According to the European Committee (EC), this index is derived for identifying whether a dose criterion is met. The index is correlated with the annual dose due to excess external gamma radiation caused by superficial, material. The value $I_\gamma = 2$ corresponds to 0.3 mSv/y, while $I_\gamma = 6$ corresponds to = 1 mS/y. according to this dose criterion, the material with $I_\gamma = 6$ should be avoided, since this value corresponds to dose rate higher than 1 mSv/y [18]. The latter value represents the highest value of dose rate in air recommended for population.

The absorbed gamma dose rate (D) in air at 1 m above the ground surface for uniform distribution of ^{226}Ra, ^{232}Th and ^{40}K radionuclides was calculated and derived and reported by [12] using equation (5):

$$D\ (nGy/h) = 0.461\ A_{Ra} + 0.623\ A_{Th} + 0.041\ A_K \quad (5)$$

The world average value of the absorbed dose rate is 60 nGy/h. To make a rough estimate for the annual ambient dose, the conversion coefficient from absorbed dose in air to effective dose and the outer occupancy factor must be taken into account. [12] committee used 0.7 $Sv.Gy^{-1}$ as the conversion coefficient from absorbed dose in air to effective dose received by adults and 0.2 for the outdoor occupancy factor, suggesting that the people spend about 20% of their time outdoors. Also, it is assumed that the annual average time for exposure to radiation is 8760 hours. Accordingly, the annual effective dose rate (AEDR) given in mSv/y is calculated as:

$$AEDR = \text{Dose rate (nGy/h)} \times 8760\ h \times 0.2 \times 0.7 \times 10^{-6} \quad (6)$$

The recommended value of AEDR is 20 mSv/y for the occupational members and 1 mSv/y for publics [19]. The annual gonadal dose equivalent AGDE [12] due to the specific activities of ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K radio nuclides was calculated using equation (7).

$$AGDE = 3.09\ A_{Ra} + 4.18\ A_{Th} + 0.31\ A_K \quad (7)$$

RESULTS AND DISCUSSION

A total of forty six representative samples were collected from Mir area for the two regions A and B. The activity concentrations of ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K radionuclides were given in Tables (2A & 2B).

Some variation diagram showing the inter relationships between different radio nuclides in the measured samples of the two region A and B As given in Figs. (2A&2B) and Figs. (3A&3B) respectively.

The obtained data indicate that for samples of the region A, the ^{238}U activities is varied from 11.01 to 94.99 with an average value of 29.13 Bq/kg. ^{232} Th ranged from 1.32 to 6.43 with an average value of 3.73 Bq/kg while ^{226}Ra ranges from 5.93 to 85.48 with an average of 24.90 Bq/kg; and ^{40}K ranges from 2.70 to 61.38 with an average of 23.28 Bq/kg. The activity concentrations of ^{238}U for A14 (94.99 Bq/kg) exceeds permissible level 40 Bq/kg [UNSCEAR 2000] as shown in Fig. (2A).

For samples of the region B the ^{238}U specific activities varied from 5.18 to 41.69 with an average value of 19.94 Bq/kg. ^{232}Th ranged from 1.73 to 8.57 with an average value of 4.10 Bq/kg, ^{226}Ra ranged from 4.09 to 38.82 with an average value of 17.01 Bq/kg and ^{40}K varies from 4.00 to 31.23 with an average value of 15.96 Bq/kg as shown in Fig. (2B). The activity concentrations of ^{232}Th and ^{40}K for region A and B as shown in Fig. (2A & 2B) were in permissible levels for ^{238}U , ^{232}Th and ^{40}K except for samples A 14 and B15 for ^{238}U.

The inter-element variation diagrams show that U is positively correlated with Ra as shown in Fig. (3A) and weakly correlated with Th Fig (3B). The correlation between Th and both of Ra and K is very weak as shown in figs. (3C & 3D). This reflects the geochemical behavior of the concerned radionuclides.

The contributions of the concerned radionuclides in the air absorbed dose rate for the two regions are represented in (Figs 3A, 3B), respectively, which show that the main contribution due to ^{226}Ra.

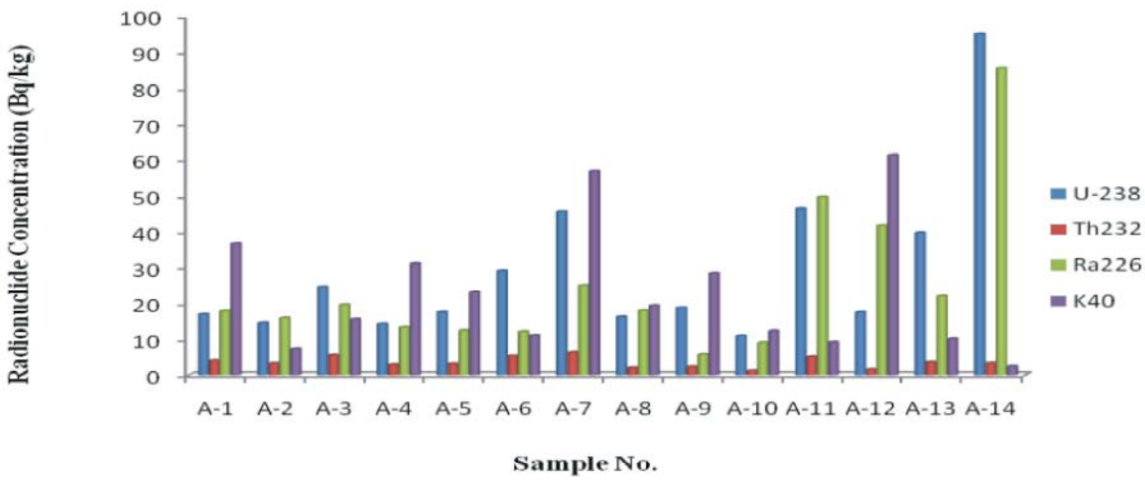

Fig. 2A: Activity concentration due to natural radionuclides in different samples in region A

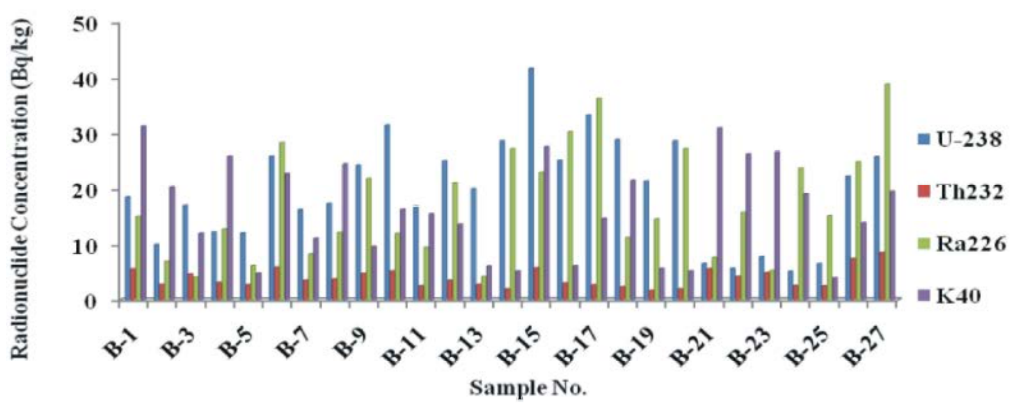

Fig. 2B: Activity concentration due to natural radionuclides in different samples in region B

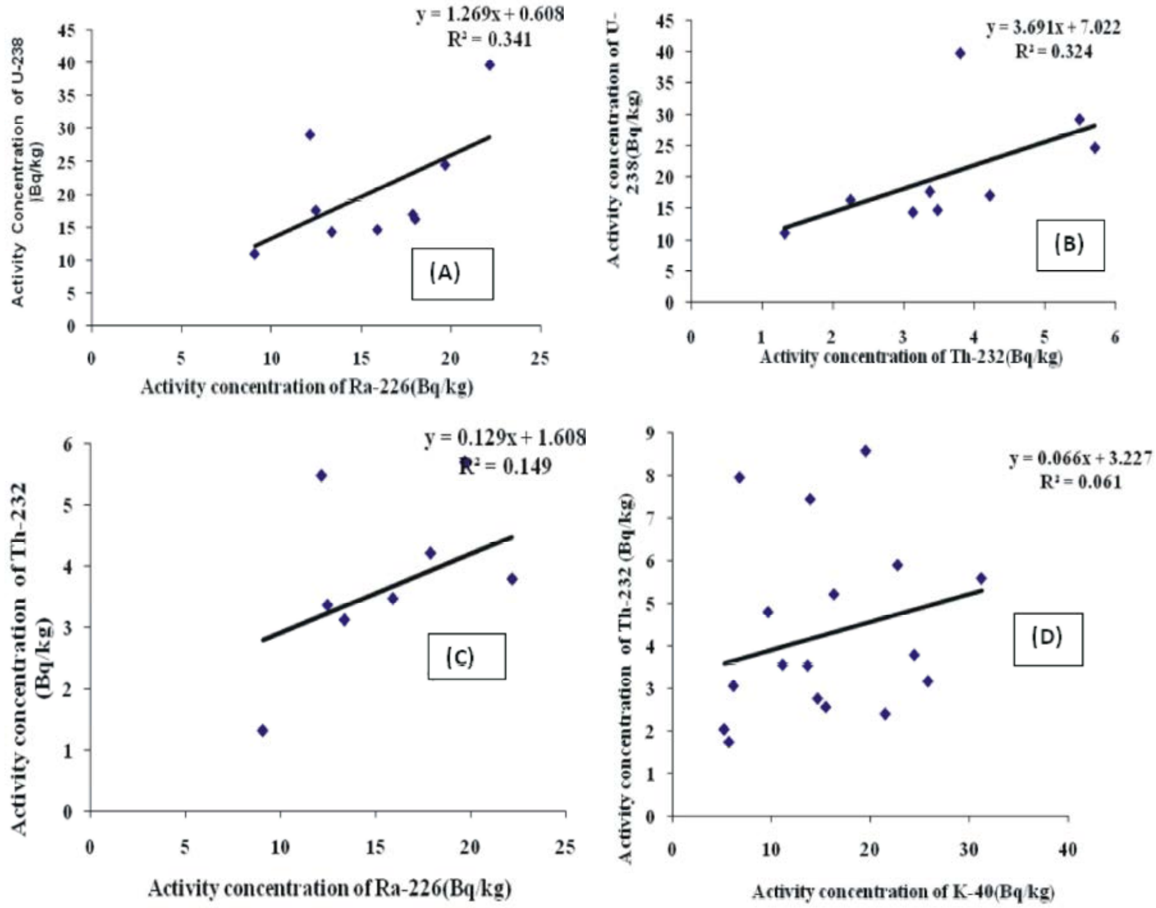

Fig. 3: The correlation between different natural radionuclides activity for different samples

Table 2A: Activity concentration of U-238, Th-232, Ra- 226and K-40 for samples in region A

	Radionuclides activity (Bq/Kg)			
Sample No.	U-238	Th232	Ra226	K40
A-1	16.98	4.22	17.89	36.73
A-2	14.66	3.48	15.92	7.42
A-3	24.54	5.71	19.69	15.610
A-4	14.32	3.13	13.38	31.09
A-5	17.60	3.37	12.49	23.30
A-6	29.12	5.49	12.17	11.13
A-7	45.76	6.43	24.97	56.87
A-8	16.26	2.25	18.02	19.47
A-9	18.85	2.55	5.93	28.39
A-10	11.01	1.32	9.09	12.33
A-11	46.48	5.24	49.69	9.22
A-12	17.58	1.73	41.69	61.38
A-13	39.70	3.80	22.17	10.21
A-14	94.99	3.53	85.47	2.70
Min. activity	11.01	1.32	5.93	2.70
Max. activity	94.99	6.43	85.48	61.38
Average activity	29.13	3.73	24.90	23.28

Table 2B: Activity concentration of U-238, Th-232, Ra- 226 and K-40 for samples in region B

	Radionuclides activity (Bq/Kg)			
Sample No.	U-238	Th232	Ra226	K40
B-1	18.50	5.58	15.04	31.23
B-2	10.02	2.83	6.92	20.27
B-3	17.02	4.64	4.09	12.05
B-4	12.28	3.16	12.80	25.86
B-5	12.10	2.77	6.20	4.83
B-6	25.88	5.89	28.29	22.78
B-7	16.28	3.55	8.34	11.14
B-8	17.34	3.78	12.19	24.47
B-9	24.27	4.79	21.87	9.67
B-10	31.42	5.21	12.02	16.31
B-11	16.67	2.55	9.52	15.49
B-12	25.03	3.53	21.05	13.65
B-13	19.99	2.81	4.23	6.09
B-14	28.61	2.03	27.20	5.21
B-15	41.69	5.80	22.99	27.56
B-16	25.12	3.05	30.24	6.15
B-17	33.25	2.75	36.26	14.66
B-18	28.84	2.39	11.29	21.52
B-19	21.41	1.73	14.57	5.69
B-20	28.61	2.03	27.20	5.21
B-21	6.55	5.62	7.64	30.94
B-22	5.71	4.27	15.75	26.26
B-23	7.77	4.91	5.31	26.64
B-24	5.18	2.59	23.72	19.06
B-25	6.53	2.53	15.14	4.00
B-26	22.28	7.44	24.88	13.91
B-27	25.81	8.57	38.82	19.54
B-28	24.17	7.95	12.65	6.77
Min. activity	5.18	1.73	4.09	4.00
Max. activity	41.69	8.57	38.82	31.23
Average activity	19.94	4.10	17.01	15.96

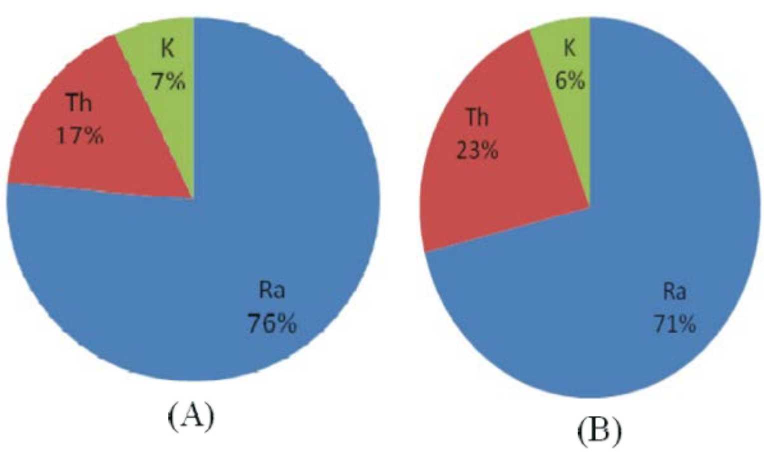

Fig. 4: The exposure contributions due to the concerned radionuclides in two regions, A: A region, B: B region

Table 3A: Hazard indices (Ra_{eq}, H_{ex}, H_{in}, I_{γ}, D and AEDR) for different samples in region A

	Environmental radiation indices					
Sample No.	Ra eq (Bq/kg)	H_{ex}	H_{in}	I_{Gamma} (Bq/kg)	Absorbed gamma dose rate (nGy/h)	AEDR (mSv/y)
A-1	26.76	0.072	0.121	0.093	12.38	0.015
A-2	21.47	0.058	0.101	0.073	9.81	0.012
A-3	27.85	0.078	0.132	0.100	13.27	0.016
A-4	20.25	0.055	0.091	0.071	9.39	0.012
A-5	19.11	0.052	0.085	0.067	8.81	0.011
A-6	20.88	0.056	0.089	0.072	9.49	0.012
A-7	38.54	0.104	0.172	0.135	17.85	0.022
A-8	22.73	0.061	0.110	0.088	10.51	0.013
A-9	11.76	0.032	0.048	0.042	5.49	0.007
A-10	11.94	0.032	0.057	0.041	5.52	0.007
A-11	57.89	0.156	0.291	0.195	26.55	0.033
A-12	48.89	0.132	0.245	0.168	22.81	0.028
A-13	28.39	0.077	0.137	0.097	13.01	0.016
A-14	90.73	0.245	0.476	0.304	41.71	0.051
Min.	11.76	0.032	0.048	0.041	5.49	0.007
Max.	90.730	0.245	0.476	0.304	41.71	0.051
average	31.94	0.09	0.15	0.110	14.76	0.020
Permissible values	370	1	1	1	59	1 for public & 20 for worker

Table 3B: Hazard indices (Ra_{eq}, H_{ex}, H_{in}, I_{γ}, D and AEDR) for different samples in region B.

	Environmental radiation indices					
Sample No.	Ra eq (Bq/kg)	H_{ex}	H_{in}	$I_{\gamma\,(Bq/kg)}$	Absorbed γ dose rate (nGy/h)	AEDR (mSv/y)
B-1	25.43	0.069	0.109	0.177	11.69	0.014
B-2	12.52	0.034	0.053	0.088	5.78	0.007
B-3	11.66	0.031	0.043	0.082	5.27	0.006
B-4	19.31	0.052	0.087	0.134	8.93	0.011
B-5	10.53	0.028	0.045	0.072	4.78	0.006
B-6	38.47	0.104	0.180	0.263	17.64	0.022
B-7	14.27	0.039	0.061	0.099	6.51	0.008
B-8	19.48	0.053	0.086	0.135	8.98	0.011
B-9	29.47	0.080	0.139	0.200	13.47	0.017
B-10	20.74	0.056	0.089	0.143	9.46	0.012
B-11	14.36	0.039	0.065	0.099	6.61	0.008
B-12	27.15	0.073	0.130	0.185	12.46	0.015
B-13	8.715	0.024	0.035	0.060	3.95	0.005
B-14	30.51	0.082	0.156	0.205	14.02	0.017
B-15	33.40	0.090	0.152	0.230	15.34	0.019
B-16	35.08	0.095	0.177	0.236	16.09	0.020
B-17	41.32	0.112	0.210	0.279	19.03	0.023
B-18	16.36	0.044	0.075	0.113	7.57	0.009
B-19	17.47	0.047	0.087	0.118	8.02	0.010
B-20	30.51	0.082	0.156	0.205	14.02	0.017
B-21	18.05	0.049	0.069	0.128	8.29	0.010
B-22	23.89	0.065	0.107	0.165	11.00	0.013
B-23	14.37	0.039	0.053	0.102	6.60	0.008
B-24	28.90	0.078	0.142	0.197	13.33	0.016
B-25	19.06	0.052	0.092	0.129	8.72	0.011
B-26	36.59	0.099	0.166	0.250	16.68	0.020
B-27	52.59	0.142	0.247	0.358	24.04	0.029
B-28	24.54	0.066	0.103	0.168	11.06	0.014
Min activity	8.715	.024	0.035	0.060	3.95	0.005
Max activity	52.59	0.142	0.247	0.358	24.04	0.029
average activity	24.098	0.065	0.111	0.165	11.048	0.014
Permissible values	370	1	1	1	59	1 for public & 20 for worker

The calculated six environmental hazard indices (Ra_{eq}, H_{ex}, H_{in}, I_{γ}, D and AEDR) are tabulated in Table (4A & 4B) for A and B regions which reveal that all values were less than the permissible values.

CONCLUSIONS

It could be concluded that, the studied sedimentary rocks of both regions A and B have normal radiation levels. The environmental hazard indices all values are within the permissible values. No environmental impacts are expected due to natural radiation. This means that the study area is safe for the population when it is used for agricultural and other purposes.

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