



Ain Shams University
Faculty of Science
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***Elemental and Radioactivity Concentration in Some
Environmental Samples from South Sinai***

A Thesis

Submitted in Partial Fulfillment for the requirements of the
Degree of Master of Science in Physics

By

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Radionuclides Concentrations and the Assessment of the Absorbed Dose Received By Workers at Um Bogma Area, Sinai, Egypt

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Abstract

Um Bogma area has an open industrial field and is considered to be one of the most rich region in natural resources in Egypt. Therefore, safety rules for workers should be precisely estimated and strictly applied. The concentrations and distributions of natural radionuclides for sedimentary twenty two rock samples from Um Bogma which subdivided into four localities [Abu Zarab (AZ), Sad Elbanat (SB), Talet Selim (TS) and Allouga (AG)] have been measured using gamma spectroscopy technique. These measurements are very important to detect the harmful effects associated with the existing high radioactivity levels in Um Bogma area, Sinai. The radiation hazard parameters, such as absorbed dose rate, the annual effective absorbed dose rate, external hazard index, and internal hazard index were calculated from the measured concentrations of natural radioactivity. The average concentration values of ^{238}U , ^{232}Th , and ^{40}K in the surveyed samples are $(637.849 \pm 4.626) \text{ Bq kg}^{-1}$ for ^{238}U , $(45.4784 \pm 1.9) \text{ Bq kg}^{-1}$ for ^{232}Th and $(406.4345 \pm 7.55) \text{ Bq kg}^{-1}$ for ^{40}K .

Keywords: Natural radioactivity, Radionuclides, Hazards parameters, Sinai.

1. Introduction

The distribution of radioactive materials and thus the level of radioactivity on the surface of the earth differ from one region to another depending on the difference in the geological characteristics and the type of industrial applications [1-3]. Natural radionuclides are present in all rocks in varying amounts depending on their concentration levels in source rock materials.

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It is known that the radionuclides ^{238}U , ^{235}U and ^{232}Th are incorporated in igneous materials when they are originally formed from the molten state [4-5]. Rocks, sand and soils contain uranium and thorium series with different concentrations [6]. Most materials contain ^{238}U and are consequently potential radon emitters since ^{222}Rn is a daughter product of ^{226}Ra . Construction materials are sources of indoor airborne radioactivity and external radiation from the decay of the natural series and ^{40}K in buildings [7-9].

Sinai Peninsula has a special interest in natural resources prospecting (petroleum, mineral deposits and groundwater), which could be of great value for development purpose. The southwestern part of Sinai is considered as one of the most promising areas for heavy metal mineralization in Egypt, being rich in mineral deposits such as manganese, iron, copper, zinc, lead, cobalt, nickel, silver and uranium [10-13]. Additionally, some industrial ore minerals such as kaolin and glass sand are being produced. As a consequence, the aim of the present work is to have an accurate evaluation of the radioactivity levels in order to draw suitable plans for important mineral and ore exploration along with the application of effective safety rules for workers to be far from radiation exposure risks.

2. Materials and Methods

Twenty-two rock samples were collected during August 2013 from four main regions in southwestern Sinai, Egypt (Fig. 1). These regions are Abu Zarab (AZ), Sad Elbanat (SB), Talet Selim (TS) and Allouga (AG).

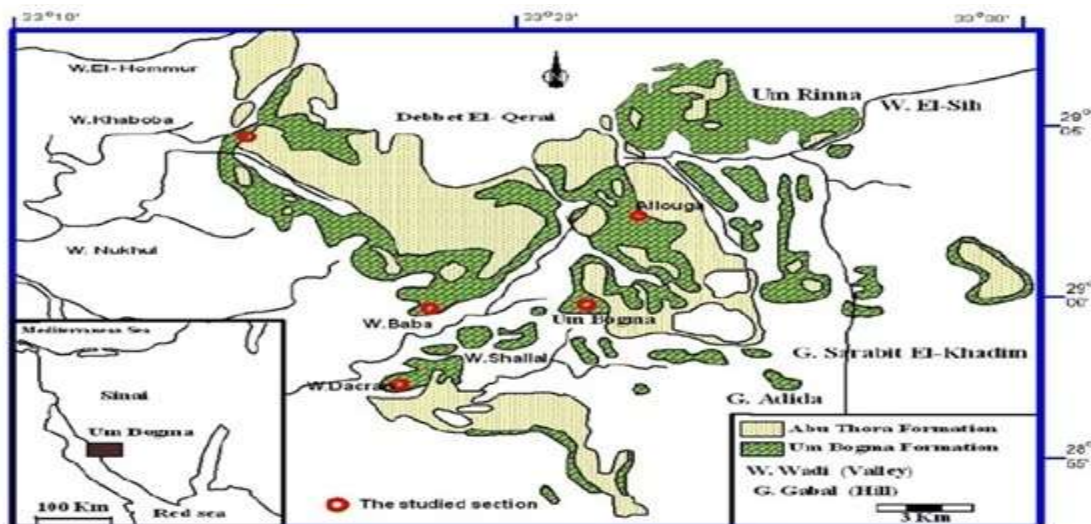


Fig (1): Map of the studied area

The samples were stored for four weeks to reach secular equilibrium between ^{238}U and ^{232}Th and their corresponding progenies. The sampling sites are almost systematically distributed within the study area and well distributed to get samples highly representative for the studied area. The radionuclides concentrations of the collected samples were measured using HPGe gamma-spectrometer. The spectrometer was adjusted, calibrated for both energy and efficiency. The background was carefully measured and subtracted. The HPGe gamma-spectrometer with 40% efficiency and 2.0 keV energy resolutions at 1.33 MeV photons of ^{60}Co was shielded by 4 mm Pb, 1 mm Cd and 1 mm Cu. The specific activity concentration of ^{40}K was estimated directly by its gamma-line of 1460.8 keV. The specific activity concentration of ^{226}Ra were determined indirectly by using γ -lines 351.9 keV from ^{214}Pb and 609.3 keV, 768.4 keV, 1120.3 keV, 1238.1 keV and 1769.5 keV from ^{214}Bi . For ^{232}Th , The specific activity concentration were determined by using the gamma lines 338.4 keV from ^{228}Ac , 583.1 keV from ^{208}Tl , 911.2 keV, 968.9 keV and 974.7 keV from ^{228}Ac . The average counting time interval for samples is varying from 69.000 to 79.000 seconds.

Health hazard parameters

The radiological effects from the rock samples containing different amounts of ^{226}Ra , ^{232}Th and ^{40}K can be obtained by computing a common index called the radium equivalent activity (Ra_{eq}) in Bq/kg. It is calculated using the following relation [14].

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.07C_K \quad (1)$$

where, C_{Ra} , C_{Th} and C_K are the activity concentrations (Bq/kg) of ^{226}Ra , ^{232}Th and ^{40}K respectively.

The gamma absorbed dose rate in the air (D) is calculated from the measured activities of ^{226}Ra , ^{232}Th and ^{40}K in rock as follows: [14]

$$D(nGyh^{-1}) = 0.427C_{Ra} + 0.662C_{Th} + 0.0432C_K \quad (2)$$

The external and internal hazard indices (H_{ex} , H_{in}) is defined as [15]

$$H_{in} = C_{Ra}/185 + C_{Th}/259 + C_K/4810 \quad (3)$$

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 \quad (4)$$

The value of this index must be less than unity in order to keep the radiation hazard insignificant. The maximum value of ($H_{ex} = 1$) corresponds to the upper limit of radium equivalent activity (370 Bq/kg).

Considering 0.7 mSv/Gy conversion coefficient from absorbed dose in air to effective dose and the indoor occupancy factor 0.2 (people on the average, spent 20% of their time outdoors) [14] the annual effective doses are calculated as follows:

$$\begin{aligned} \text{Annual effective dose (mSv/y)} \\ = D(\text{Gy}) \times 24(\text{h}) \times 365(\text{d}) \times 0.7 \times 0.2 \end{aligned} \quad (5) \quad (\text{Out door})$$

$$\begin{aligned} \text{Annual effective dose (mSv/y)} \\ = D(\text{Gy}) \times 24(\text{h}) \times 365(\text{d}) \times 0.7 \times 0.8 \end{aligned} \quad (6) \quad (\text{In door})$$

The representative level index I_γ is defined as follows

$$I_\gamma = C_{Ra}/150 + C_{Th}/100 + C_K/1500 \quad (7)$$

3. Results and Discussion

The specific activity concentrations of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K for all the selected samples, together with the corresponding location of each one, are shown in Table (1) and figure (1). The average activity concentration of ^{226}Ra (Bq/kg) ranged from 21.248 ± 0.88 to 4292.5 ± 13.3 with an average 637.85 ± 4.626 . The activity for ^{232}Th (Bq/kg) ranged from 6.68 ± 0.64 to 102.019 ± 2.78 with an average 47.04918 ± 1.9 . Finally the obtained results for ^{40}K (Bq/kg) ranged from 5.37 ± 0.4 to 1035.34 ± 13.25 with an average 406.4345 ± 7.55 .

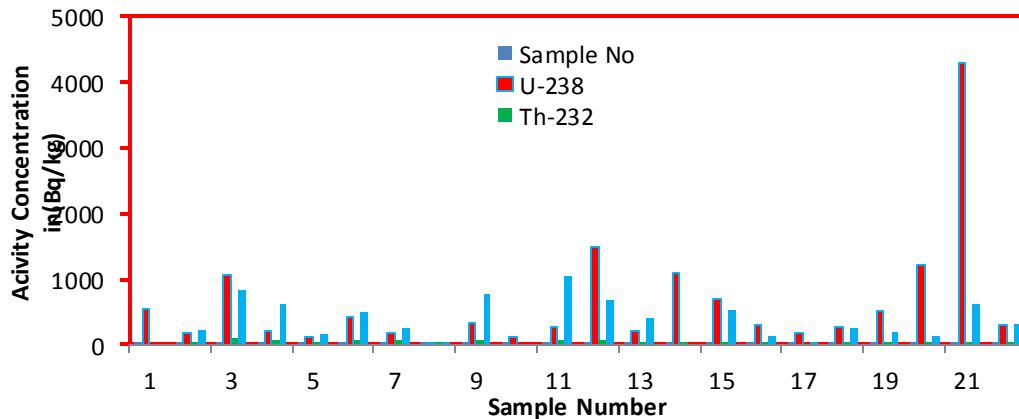


Fig (1): Histogram comparing the activity concentration ^{226}Ra , ^{232}Th and ^{40}K

Table (1): The activity concentrations of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K given in (Bq kg^{-1})

Sample Code	Site	Ra-226(Bq kg^{-1})	Th-232(Bq kg^{-1})	K-40(Bq kg^{-1})
AZ1	Abu Zarab	555.3298±4.09	15.623±1.23	202.36±2.03
AZ2	Abu Zarab	183.66±2.35	54.28±1.465	222.05±5.03
AZ3	Abu Zarab	1050.466±6.37	102.019±2.78	821.62±11.93
AZ4	Abu Zarab	209.74±2.9	83.56±1.98	612.67±8.68
AZ5	Abu Zarab	117.33±2.022	16.35±0.99	163±4.69
AZ6	Abu Zarab	426.236±4.17	59.545±2.03	512.36±9.6
AZ7	Abu Zarab	169.568±2.7	67.61±1.9	257±6.13
AZ8	Abu Zarab	21.248±0.88	6.68±0.64	33±2.09
AZ9	Abu Zarab	327.358±3.7	83.237±2.28	783.9±10.5
AZ10	Abu Zarab	117.072±2.044	13.25±1.99	160±2.69
AZ11	Abu Zarab	258.534±3.8	83.95±2.57	1035.34±13.25
AZ12	Abu Zarab	1482.352±8.4	80.475±3.4	688±14.65
SB1	Sad AlBanat	206.42±2.96	49.186±1.33	395.9±9.13
SB2	Sad AlBanat	1106.2±8.84	56.55±2.99	810.62±2.93
AG1	Allouga	701.36±4.79	52.7±1.9	531.44±10.08
AG2	Allouga	293.9±3.38	19.05±0.8	145.7±4.3
AG3	Allouga	188.36±5.9	45.15±1.23	5.37±0.4
TS1	TaletSeleim	266.9±5.25	46.28±3.15	266.9±4.7
TS2	TaletSeleim	524.79±5.7	11.6±1.7	198.5±8.8
TS4	TaletSeleim	1216.97±4.15	28.43±1.8	141.4±9.47
TS5	TaletSeleim	4292.5±13.3	51.5±3.8	634.37±18.18
TS6	TaletSeleim	316.38±4.08	8.77±0.5	320.06±6.9
Mean		637.849±4.626	47.04918±1.9	406.4345±7.55

The ratios ^{238}U (^{226}Ra)/ ^{40}K , $^{232}\text{Th}/^{40}\text{K}$, and $^{232}\text{Th}/^{238}\text{U}$ (^{226}Ra) were estimated and listed in table (2). The ^{238}U (^{226}Ra)/ ^{40}K ratio exhibits values is varying from 0.5 to 35.07 with an average value of about 3.27. This ratio is important for uranium exploration because it determines the uranium existing levels in the investigated area. The high values of ^{238}U (^{226}Ra)/ $^{40}\text{K} > 1$ are distributed all over the area with variable sizes and amplitudes. In contrary, the value of the ratio $^{232}\text{Th}/^{40}\text{K}$ illustrates that Um Bogma area does not represent a beneficial ^{232}Th production area.

Table (2): Elemental correlation between different radionuclides in rock samples

Sample code	$^{238}\text{U} (^{226}\text{Ra})/^{40}\text{K}$	$^{232}\text{Th}/^{40}\text{K}$	$^{238}\text{U}(^{226}\text{Ra})/^{232}\text{Th}$
AZ1	2.74±2.014	0.08±0.61	35.55±3.32
AZ2	0.83±0.47	0.24±0.29	3.38±1.60
AZ3	1.27±0.53	0.12±0.23	10.29±2.29
AZ4	0.34±0.33	0.13±0.22	2.51±1.46
AZ5	0.72±0.43	0.10±0.2	7.18±2.04
AZ6	0.83±0.43	0.11±0.2	7.16±2.05
AZ7	0.66±0.44	0.26±0.3	2.51±1.42
AZ8	0.64±0.42	0.20±0.3	3.18±1.38
AZ9	0.42±0.35	0.10±0.2	3.93±1.62
AZ10	0.73±0.76	0.08±0.74	8.84±1.03
AZ11	0.25±0.28	0.08±0.19	3.08±1.48
AZ12	2.15±0.57	0.11±0.2	18.42±2.47
SB1	0.52±0.32	0.12±0.14	4.19±2.23
SB2	1.36±3.02	0.07±1.02	19.56±2.96
AG1	1.32±0.48	0.09±0.18	13.31±2.52
AG2	2.02±0.78	0.13±0.18	15.43±4.23
AG3	35.08±14.7	8.41±3.08	4.17±4.79
TS1	1±1.11	0.17±0.67	5.77±1.66
TS2	2.64±0.65	0.05±0.67	45.24±3.35
TS4	8.61±0.44	0.2±0.19	42.81±2.31
TS5	6.77±0.73	0.08±0.20	83.35±3.5
TS6	0.98±0.59	0.02±0.07	36.08±8.16
Average	3.27±1.36	0.50±0.44	17.09±2.63

Table (3) shows the calculated values of external health hazard, internal health hazard, and I_{γ} respectively as measured by the gamma spectrometric technique. The calculated average value of internal and external hazard indexes are higher than unity. Additionally the calculated values of (I_{γ}) for the studied samples are higher than the unity (except for AZ8). This result points to a dangerous effect in that region for human health. Therefore, suitable precautions and safety rules should be strictly applied if there exists any industrial activity.

Table (3): Hazards parameters of the investigated samples

Sample code	H _{in}	H _{ex}	I _γ
Az1	3.104	1.603	3.993
AZ2	1.2482	0.752	1.915
AZ3	6.243	3.404	8.571
AZ4	1.584	1.017	2.642
AZ5	0.731	0.414	1.054
AZ6	2.640	1.488	3.779
AZ7	1.231	0.773	1.978
AZ8	0.148	0.090	0.230
AZ9	2.254	1.369	3.537
AZ10	0.717	0.401	1.019
AZ11	1.934	1.235	3.246
AZ12	8.466	4.460 6	11.146
SB1	1.388	0.830	2.132
SB2	6.198	3.208	8.481
AG1	4.105	2.209	5.557
AG2	1.692	0.898	2.247
AG3	1.194	0.685	1.711
TS1	1.677	0.956	2.420
TS2	2.937	1.519	3.747
TS4	6.729	3.440	8.492
TS5	23.533	11.932	29.554
TS6	1.810	0.955	2.410

Absorbed dose rates and annual effective dose rates (indoor and outdoor) for the samples under investigation were calculated and listed in table (4). The dose rate range is from (15.227 n Gy/h) to (2020.137 n Gy/h) with an average (340.0522n Gy/h).there for, the average dose rate is larger than the world average dose rate(55 n Gy/h).The minimum, the maximum and the average values for outdoor are 0.019mSv/y, 2.504mSv/y and 0.417mSv/y, respectively and the corresponding indoor values are 0.078mSv/y, 10.018mSv/y and 1.669mSv/y respectively.

Table (4): Dose rate (nGy/h), indoor and outdoor annual effective dose rate (mSv/y) due to γ -radiation

Sample code	Raeq	Dose rate	AEDR (indoor)	AEDR (outdoor)
Az1	593.252	274.437	1.347	0.337
AZ2	278.378	126.896	0.623	0.156
AZ3	1259.618	581.196	2.853	0.713
AZ4	376.406	172.918	0.849	0.212
AZ5	153.262	70.879	0.3479	0.087
AZ6	550.837	254.252	1.248	0.312
AZ7	286.039	129.894	0.638	0.159
AZ8	33.341	15.227	0.078	0.019
AZ9	506.747	234.203	1.150	0.287
AZ10	148.339	68.762	0.337	0.084
AZ11	457.284	212.892	1.045	0.261
AZ12	1650.407	762.143	3.741	0.935
SB1	307.240	141.583	0.695	0.174
SB2	1249.484	579.024	2.842	0.711
AG1	817.642	378.020	1.856	0.463
AG2	332.360	153.364	0.753	0.188
AG3	253.338	114.517	0.562	0.141
TS1	353.632	162.391	0.797	0.199
TS2	556.663	257.737	1.265	0.316
TS4	1268.513	585.308	2.873	0.718
TS5	4414.991	2040.694	10.018	2.504
TS6	353.566	164.811	0.873	0.202
Average	736.424	340.052	1.669	0.417

Conclusion

Um Bogma area in the south west of Sinai is considered to be one of the most expected rich mineral exploration regions in Egypt. Therefore the activity concentration of ^{226}Ra , ^{232}Th , and ^{40}K in some representative selected samples were determined using high resolution gamma spectrometry technique. The obtained results for ^{226}Ra (^{238}U) and ^{232}Th are higher than the international levels which is 35 Bq/kg for the former and 50 Bq/kg for the latter. Dose assessment and hazard indices criteria were calculated and discussed. From the calculations, it is found that the absorbed dose rate, annual effective dose, internal annual effective dose and external annual effective dose due to γ -radiation and the representative level index I_γ exceed the

regular limits, which may represent an environmental risk to public and workers. The data obtained in this work can serve as a database for the assessment of the existing radiation hazard from which safety rules for workers could be easily drawn and applied.

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

وَقُلْ رَبِّ زِدْنِي عِلْمًا

In the Name of Allah, the Most Gracious, the Most Merciful

“..And Say: My Lord! Increase me in Knowledge”

“TAHA/114, the Glorious QurAn”