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Tissue Annual Effective Doses Estimation from Natural Occurring Radioactive Materials at Ramlet Homyier Area - South Western Sinai, Egypt

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Abstract

γ -ray spectrometric survey shows many radioactive anomalies within the ferruginous siltstone of the lower Um Bogma Formation. The high average eU/eTh values indicate an addition of uranium (migration in) in both the two regions. The results obtained from field measurements show that the indoor annual effective dose in Ramlit Homyier and Heboush area are (48.71 mSv) and (19.70 mSv) respectively while that estimated by HPGE detector were (1.90 and 0.08 mSv). According to AEDE obtained, the dose delivered to each tissue is estimated and it reveals high dose risk to public derived from the exposure to subsurface NORM in Ramlet Homyier more than Heboush area for most body tissues. Consequently staying in such levels of NORM requires a high caution and awareness to minimize the health risk accompanied to daily exposure of public and applying radiation protection principals to achieve a better safe working and living environment.

Keywords: radon, tissue, dose.

Introduction

Ramlet Homyier area lies in southwestern Sinai, about 70 Km, to the southeast of Abu Zenima city. It is a low mountainous area with large sheeted sand covers. It is delineated by longitudes [33° 24' 18" and 33° 31' 30"E] and latitudes [29° 00' 36" and 29° 04' 30" N] Figure (1). Ramlet Homyier area is covered by Precambrian igneous rocks, which are unconformably overlies by a thick Palaeozoic sequences up to reach about 245 m.

The Precambrian rocks are generally differentiated from oldest to youngest into: gneisses and schist, diorites, older granitoids (granodiorite), younger granites and dykes [1, 2, 3].

The Paleozoic sedimentary rocks in the east Abu Zenima of southwest Sinai, including the study area, are of great importance especially from the mineralogical and radioactive points of view.

Natural environmental components such as soils, rocks, sediments, vegetation, air and water include some naturally occurring radioactive materials (NORM). These materials may contain ^{238}U , ^{235}U , ^{232}Th , ^{226}Ra and their radioactive daughters, and the primordial radioactive isotope ^{40}K . These radio nuclides give rise to internal and external radiation exposures both indoor and outdoor.

The present study determines the environmental radioactivity hazards indices and the exposure dose rate for the public from collected samples of rocks and soil and its influence on every body tissues.

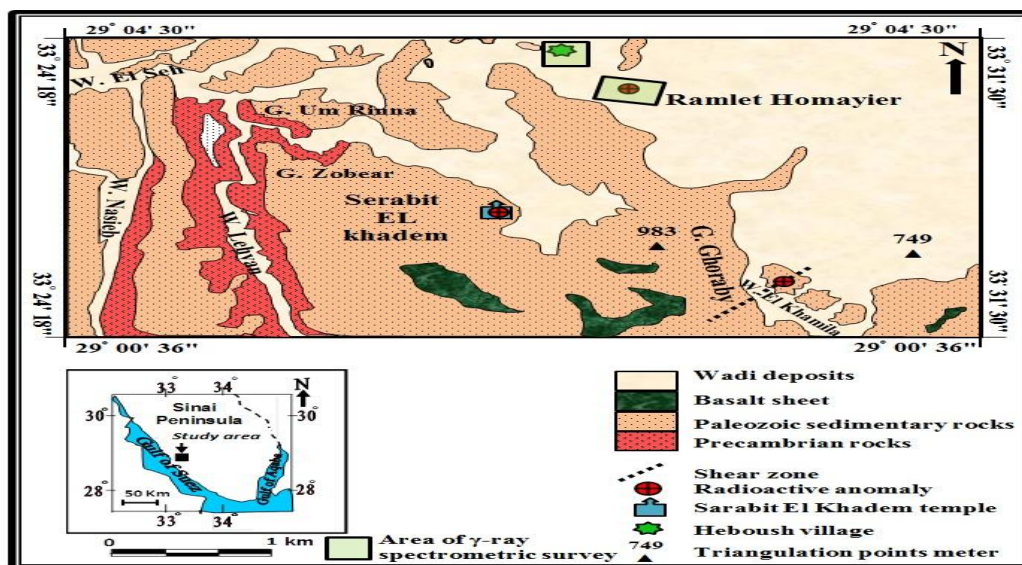


Fig. 1: Geologic map of Ramlet Homayier area

For the Paleozoic succession the main subdivisions, include three major lithostratigraphic units that comprise from base to top: a) Sarabit El Khadim, Abu Hamata and Adedia Formations as discussed by Soliman and Abu El Fetouh [1], b) Um Bogma Formation [2]. c) El-Hashash, Magharet El-Maiah and Abu Zarab Formations [1], Abu Thora Formation [3]. The unconformity surfaces were recorded between Um Bogma Formation and other lower and upper formations figure (1)

The succession of the Paleozoic rocks exposed in most parts of the mapped area consists of seven formations namely from the oldest to youngest: Sarabit El Khadim, Abu Hamata, Adediya, Um Bogma, El Hashash, Magharet El Maiah and Abu Zarab Formations.

Um Bogma Formation is the most important formation in the Paleozoic succession from the radioactivity and mineralization points of view.

Materials and Methods

The field radiometric measurements of eU (ppm), eTh (ppm) and K% were obtained using a portable differential gamma ray spectrometer model Rs-230 BGO Super-Spec, serial No. 4333, the reading were given directly each 30 second.

Two techniques were used measurements of the annual effective dose.

i) Radon gas measurements using Solid State Nuclear Track Detectors (SSNTD):

In this technique, a closed cup contains SSNTD's was used according to the following procedures.

The applying of closed cup technique in which the detector after cutting into pieces of about 1 cm^2 and, numbered then, hanged at the inside volume of the cup from the bottom is inserted inside a close can (cup) with specific dimensions, then covered with a filter paper or a membrane. This configuration admits detectors only radon gas through diffusion process but exclude its decay products. Radon gas inside the enclosure decays through its chain of decay products, producing a track density which is proportional to the detector's radon gas exposure [4].

After exposure time (30 day), the cups were recovered and the detectors were collected and chemically etched

in a thermostatically-controlled water bath at specified temperatures with an aqueous solution of NaOH at specified molarities and etching times, the etchant solution is 6.25 N NaOH and the etching temperature was maintained at (70 ± 1) °C for 8 hours.

The detectors were rinsed in flowing cold water, in order to stop quickly the etching action of the etchant left in the tracks. Then washed, with distilled water and dried to be ready for counting under a transmission optical microscope. The microscope magnifications of 400X. A number of fields were counted, for each detector.

- Radon gas concentration and annual effective dose calculation

The radon gas concentration (Bq.m^{-3}) calculated from the formula [4]

$$C_{\text{Rn}} (\text{Bq/m}^3) = \rho / K \quad (1)$$

Where,

ρ : The track density, ($\text{T.cm}^{-2}.\text{d}^{-1}$)

K : The calibration factors, ($\text{T.cm}^{-2}.\text{d}^{-1}/\text{Bq.m}^{-3}$).

A dose coefficient of $3 \text{ mSv/mJ h m}^{-3}$ using the standard equilibrium factor assumption of $F = 0.4$ (the ratio between the concentration of radon progeny and radon-222) for most situations and this corresponds to $6.9 \times 10^{-6} \text{ mSv/Bq h m}^{-3}$ [5].

For indoor workers involving substantial physical activity, and exposures in tourist caves, ICRP recommends $6 \text{ mSv/mJ h m}^{-3}$. Using the standard equilibrium factor assumption of $F = 0.4$, this corresponds to $1.4 \times 10^{-5} \text{ mSv/Bq h m}^{-3}$ [5].

Calculating the dose from inhaling radon involves multiplying the average radon level (Bq/m^3) by time spent, and the right dose coefficient. As a result the following equations are used to calculate the annual effective dose

$$\text{Effective dose} = \text{Radon level} \times \text{Time} \times \text{Dose coefficient} \quad (2)$$

Where;

Radon level : is the radon concentration in Bq/Kg

Time : is the time spent for exposure in hour

Dose coefficient: is the conversion factor to dose from radon concentration mSv/Bqhm^{-3}

ii) Radiometric measurements γ -ray spectrometer is NaI(Tl)

The system of γ ray spectrometer consists of Bicron scintillation detector, NaI(Tl) crystal, 76x76 mm, hermetically sealed with a photomultiplier tube in aluminum housing. The detector is connected with Nuclear Enterprises main shaping amplifier, model NE- 4658, and Tennelec high voltage power supply, model, TC 952 with HV digital display. It is also connected with Nuclease PCA- 8000 computer based, 8192 multichannel analyzer with color graphical display of spectra and high level technical operation features [6].

The conversion of radioelement concentration to specific activity can be written as, for 1% ^{40}K in rock = 313 Bq/kg , 1 ppm of ^{238}U in rock = 11.06 Bq/Kg , ^{226}Ra in rock = 12.35 Bq/kg and for 1 ppm ^{232}Th in rock = 4.06 Bq/kg [7, 8].

1- The total absorbed dose rate in air (D) (nGy/h) at 1m above the ground can be calculated as [6].

$$D \text{ (nGy/y)} = 0.462 A_{Ra} + 0.604 A_{Th} + 0.0417 A_K \quad (3)$$

Where D, is the dose rate at 1m above the ground, A_U , A_{Th} and A_K are the specific activity concentration, (Bq/kg) for ^{226}Ra , ^{232}Th and ^{40}K respectively. The values 0.462, 0.604 and 0.0417 are the conversion factor (nGy/h) per Bq/kg for ^{226}Ra , ^{232}Th and ^{40}K nuclei respectively. From normal background areas, the average dose rate value is 59nGy/h [9].

2- For estimating the annual effective dose equivalent AEDE (mSv/y) from dose rate, two main factors must be introduced i) a conversion coefficient from absorbed dose in air to effective does must take in account with a value of 0.7 Sv /Gy. ii) Outdoor occupancy factor reports a value of a conversion coefficient factor from absorbed dose in air to effective dose received by adults, and 0.2 for the outdoor occupancy factor and 0.8 for indoor occupancy factor [9, 10] Then AEDE (mSv/y) can be written as:

$$\text{AEDE (mSv/ y)} = D \text{ (n Gy h}^{-1}\text{)} \times 8760\text{(h/y)} \times 0.2 \times 0.7 \text{ Sv Gy}^{-1} \times 10^{-6} \quad (4)$$

The world average annual effective dose equivalent (AEDE) from outdoor terrestrial gamma radiation is 70 $\mu\text{Sv/h}$ [11]

The International Commission of Radiological Protection (ICRP) recommended that no individual should receive more than 50 mSv/y from all natural and artificial radiation sources in his/her environment [12]. The recent recommendations of IAEA indicate that the permissible levels of dose rates reaching up to 5 mSv/y for public members and up to 20 mSv/y for the occupational members [9, 13]

3- Radiation indices factors, it gives a complete measure about how the radiation is affecting on human body.

- **Radium equivalent** is the factor introduced to establish a state of uniformity distributions of the three main radioactive nuclei as the distribution of ^{226}Ra , ^{232}Th and ^{40}K in soil is not uniform [14].

$$\text{Ra}_{eq} = A_{Ra} + (A_{Th} \times 1.43) + (A_K \times 0.077) \quad (5)$$

The recommended maximum value of Ra_{eq} is 370 Bq/kg [15].

- **External hazard index (H_{ex})**, measures the external hazard due to the emitted gamma radiation. It was calculated by the equation [16].

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

For the safe limits, (H_{ex}) should be less than unity

- **Internal hazard index (H_{in})**, the internal hazard index which controls the internal exposure to ^{222}Rn and its radioactive progeny and is given by [17].

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (7)$$

For the safe limits, (H_{in}) should be less than unity

- **Radioactivity level index (I_γ)**, estimates the level of radiation risk, especially γ -rays, associated with natural radio nuclides in specific materials [18, 19].

$$I_\gamma = \left(\frac{A_{Ra}}{150Bq/kg} + \frac{A_{Th}}{100Bq/kg} + \frac{A_K}{1500Bq/kg} \right) \quad (8)$$

Where, A_{Ra} , A_{Th} and A_K are the Activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K in Bq/kg respectively. The safety value for this index is ≤ 1 .

5- Excess Lifetime Cancer Risk (ELCR)

Gives the probability of developing cancer over a lifetime at a given exposure level, considering 70 years as the average duration of life for human being. It is given [20].

$$\text{ELCR} = \text{AEDE} \times \text{DL} \times \text{RF} \quad (9)$$

Where AEDE is the Annual Effective Dose Equivalent, DL is the average Duration of Life (estimated to be 70 years) and RF is the Risk Factor (Sv) i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for the public. The percentage risk analysis associated with this index is then given [21].

6- Annual dose limits for human tissues

The effective dose is considered for the whole body while applying a tissue weighting factor (W_T) of 1, for calculating the dose for any specific tissue inside the body it's said to be fraction of 1, different tissues are affected differently so the tissue weighting factors are not equal and are divided to three categories. Low risk (0.01), medium risk (0.05) and high risk (0.12) [22].

$W_T = 0.12$: stomach, colon, lung, red bone marrow

$W_T = 0.20$: gonads

$W_T = 0.05$: urinary bladder, oesophagus, liver, thyroid gland and breast

$W_T = 0.01$: bone surface and skin

$W_T = 0.05$: other body organs

Results and Discussion

Two locations were chosen to be studied where urban people live there and the other where they graze their animals. Heboush and Ramlet Homayier areas are the two locations where they live and graze their animals respectively. They are covered mainly by sand.

1. Heboush area

A systematic ground spectrometric survey has been taken on a grid pattern that consists of a set thirty six stations were measured radio-metrically in Heboush area forming a network of four lines; each line contains 9 stations figure (2) and (3), table (1) shows the minimum, maximum and average data. According to the γ -ray spectrometric survey, Heboush area show low eU-content ranging from 0.7 ppm to 4.4 ppm this may be attributed to that Heboush area was covered by a very thick layer of barren sand. The eU/eTh ratio is a very important index for determining uranium migration in or out. The Clark value for eU/eTh in the sedimentary rocks is equal to unity [23]. The average eU/eTh ratio of the most measured stations is 2.47.



Fig. (2) Satellite image of Heboush (south) area showing selected stations (H1-H20)

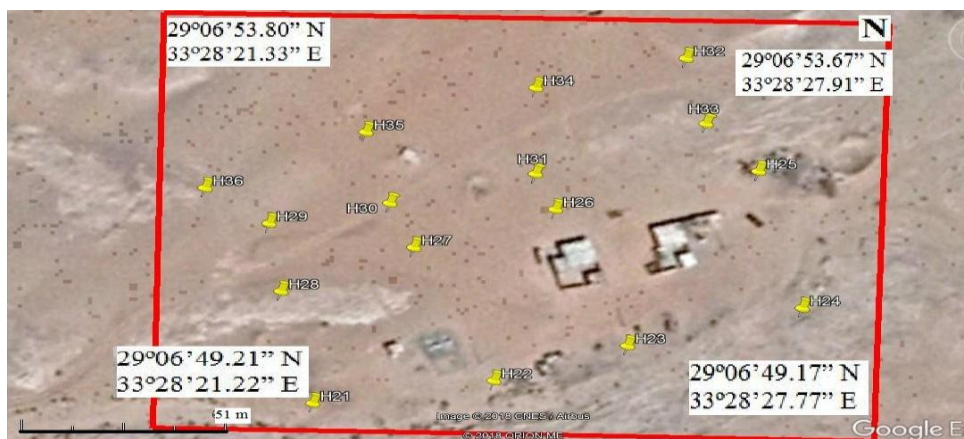


Fig. (3) Satellite image of Heboush (north) area showing selected stations (H21-H36)

Table (1) γ -ray spectrometric survey measurements in Heboush and Ramlet Homayier areas.

	eU (ppm)	eTh (ppm)	K (%)	eU/eTh
Heboush area				
Min.	0.7	0.1	0.1	0.25
Max.	4.4	6.0	0.4	29
Avg.	2.17	2.88	0.14	2.47
Ramlet Homayier area				
Min.	0.6	0.1	0.1	0.27
Max.	2303	119.2	18.4	32
Avg	76.49	11.05	0.7	12.99

2. Ramlet Homayier area

It is surveyed to search for the extension of radioactive anomalies in the area and it serves as a good location for breeding animals for the local citizens living there as they camp in the area during spring time, so an environmental investigation is also important to be done. The area was covered by a very thin layer of sand in which you can reach to the lower member of Um Bogma Formation after a few centimeters.

A systematic ground spectrometric survey has been taken on a grid pattern that consists of a set of parallel profiles trending nearly in the NW-SE. Fifty six stations were measured radio-metrically in Ramlet Homayier area forming a network of four lines; each line contains 14 stations figure (4), table (1) shows the minimum, maximum and average data. According to the γ -ray spectrometric survey many radioactive anomalies were recorded within the ferruginous siltstone of the lower Um Bogma Formation table (1) reaches more than 2300 ppm eU-content. The average eU/eTh ratio of the area is 12.99 indicating an addition of uranium (migration in).

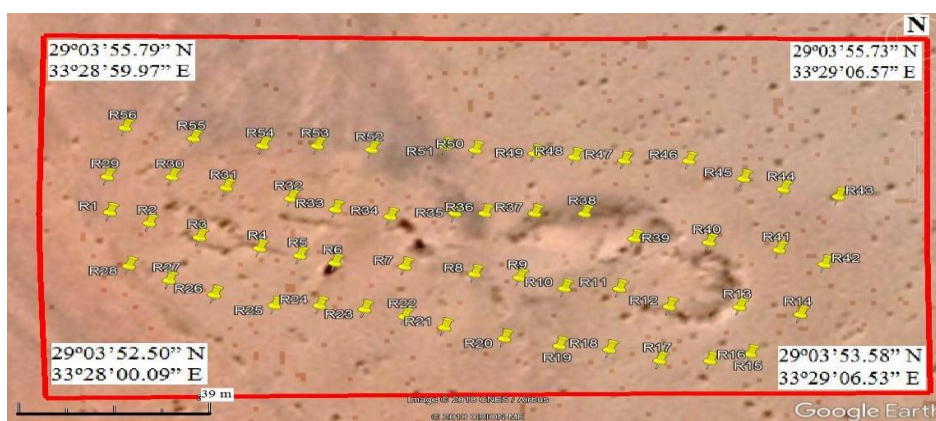


Fig. (4) Satellite image of Ramlet Homayier area showing selected stations (R1-R56)

3. Radon concentrations and Annual effective dose calculations

The results shown in table (3) for the track density and radon gas concentrations (Bq/Kg) are calculated from equation (1), the indoor and outdoor annual effective doses (mSv) are calculated using equation (2) for the average result of all selected stations of both locations.

Table (3) Track density (ρ), radon concentration and annual effective dose for each station in Hebous and Ramlet Homayier areas

	(ρ) T/cm ² .d	Rn Bq/m ³	AED (in) mSv	AED (out) mSv
Heboush area				
Min.	124.6±26	315.2±89	6.10	3.09
Max.	3062.7±651	5897.4±386	114.07	57.86
Avg.	706.9±129	1018±186	19.7	10.0

Ramlet Homayier area				
Min.	263.1±118	379.1±71	7.33	3.72
Max.	28522±2741	41098.5±3950	794.93	403.23
Avg.	1747±293	2518.45±422	48.71	24.71

In Ramlet Homayier and Heboush area the radon concentration is ranged between (379.1 ± 71 to 41098.5 ± 3950 Bq/m³) and (315.2 ± 89 to 5897.4 ± 386 Bq/m³) respectively with an average of (2518.45 ± 422 Bq/m³) and (1018.6 ± 186 Bq/m³) respectively which is higher than the world limit of (100 Bq/m³) in both locations [24]. For the indoor annual effective dose in Ramlet Homayier and Heboush area ranged between (7.33 to 794.93 mSv) and (6.10 to 114.07 mSv) respectively with an average of (48.71 mSv) and (19.70 mSv) respectively which is higher than the average world limit of (3 - 10 mSv) for both locations [13]. On the other hand the outdoor annual effective dose in Ramlet Homayier and Heboush area ranged between (3.72 to 403.23 mSv) and (3.09 to 57.86 mSv) respectively with an average of (24.71 mSv) and (10.0 mSv) respectively which is higher than the average world limit of (3 - 10 mSv) for Ramlet homayier and a border limit of Heboush area [13]. The results show that Ramlet Homayier area is having high background radioactivity due to the high subsurface abundance of NORM in that area, figure (5) and (6).

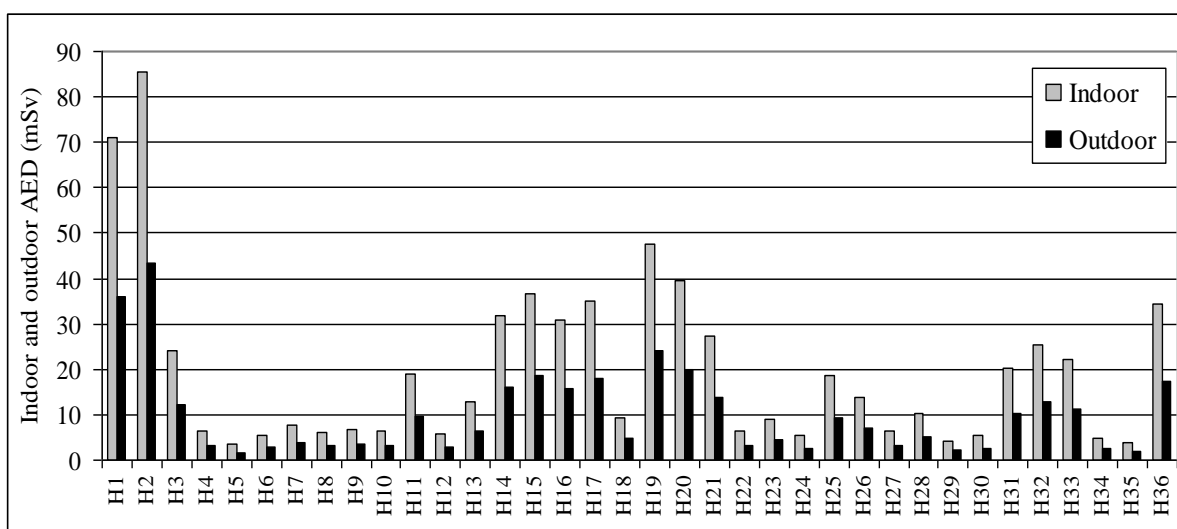


Fig. (5) Indoor and outdoor AED for all selected stations in Heboush area

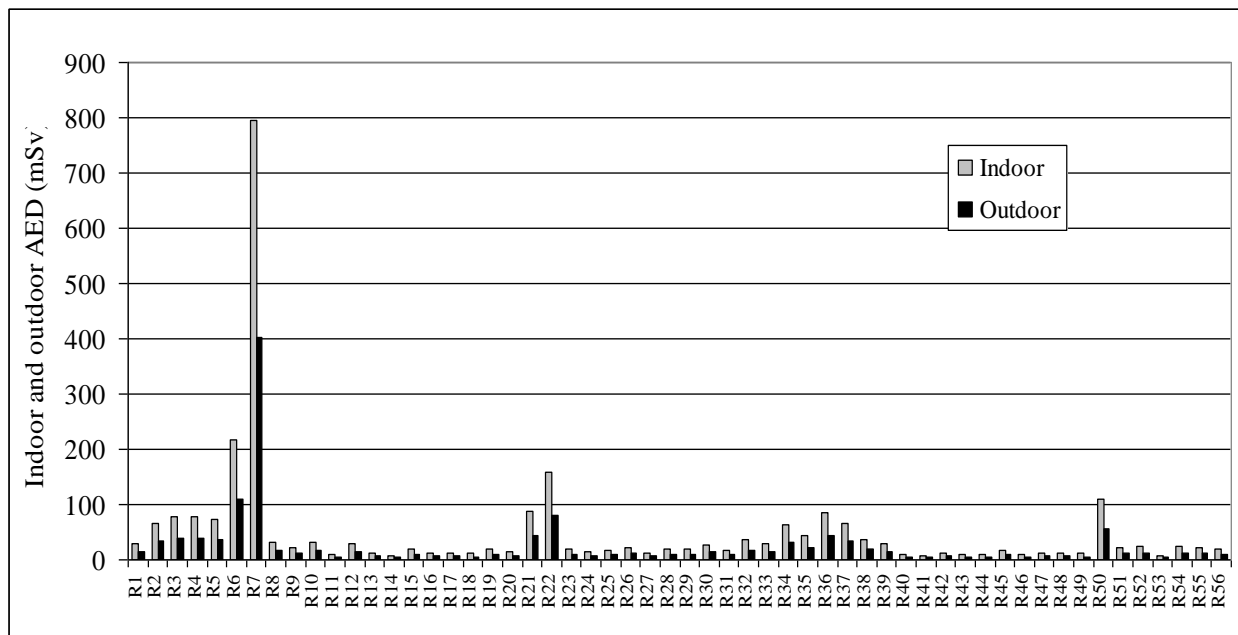


Fig. (6) Internal and external AEDE for all selected stations in Ramlet Homayier area

4. Radiometric measurements, Annual effective doses, Hazard indices and ELCR Calculations

The results shown in table (4) for the specific activity for U, Th, Ra and K in (Bq/Kg), the dose rate DR in (nGy/h) calculated using equation (3), the indoor and outdoor annual effective doses in (mSv) calculated from equation (4), the radium equivalent in (Bq/Kg) calculated from equation (5), the internal, external and gamma indices calculated from equations (6, 7 and 8) respectively and finally the excess lifetime cancer risk calculated from equation (9); for the average result of all selected stations of both locations.

Table (4) Specific activity, dose rate, indoor AED, outdoor AED and radium equivalent of selected stations in Heboush and Ramlet Homayier areas

No.	U (Bq/Kg)	Th (Bq/Kg)	Ra (Bq/Kg)	K (Bq/Kg)	DR nGy/h	AED (in) mSv	AED (out) mSv	Ra _{eq} Bq/Kg
Heboush area								
Min.	8.65	0.41	11.06	31.3	6.66	0.03	0.01	14.05
Max.	54.34	24.36	88.48	125.2	46.35	0.23	0.06	1100.76
Avg.	26.48	11.63	17.51	43.47	16.93	0.08	0.02	37.49
Ramlet Homayier area								
Min.	7.41	0.41	11.06	31.3	6.66	0.03	0.01	14.05
Max.	24625.90	483.95	5906.04	5759.2	3261.06	16.06	4.0	7041.55
Avg.	877.25	44.89	758.20	219.66	386.56	1.90	0.47	839.31

The uranium specific activity shown in table (4) in Ramlet Homayier and Heboush area ranged between (7.41 to 24625.9 Bq/Kg) and (8.65 to 54.34 Bq/Kg) respectively with an average of (877.25 and 26.48 Bq/Kg) respectively which is higher than the world average level of (50 Bq/Kg) for Ramlit Homayier area [10].

The thorium specific activity in Ramlet Homayier and Heboush area ranged between (0.41 to 483.95 Bq/Kg) and (0.41 to 24.36 Bq/Kg) respectively with an average of (44.89 and 11.63 Bq/Kg) respectively which is higher than the world average level of (40 Bq/Kg) in Ramlet Homayier area [10].

The radium specific activity in Ramlet Homayier and Heboush area ranged between (11.06 to 5906.04 Bq/Kg) and (11.06 to 88.48 Bq/Kg) respectively with an average of (758.20 and 17.51 Bq/Kg) respectively which is higher than the world average level of (40 Bq/Kg) in Ramlet Homayier area [10].

Finally the potassium specific activity in Ramlet Homayier and Heboush area ranged between (31.3 to 5759.2 Bq/Kg) and (31.3 to 125.2 Bq/Kg) respectively with an average of (219.66 and 43.47 Bq/Kg) respectively which is lower than the world average level of (500 Bq/Kg) for both locations [10]. This shows a higher level of surface radioactivity in Ramlet Homayier than Heboush area due to higher abundance of NORM.

The Dose rates shown in table (5 and 6) in Ramlet Homayier and Heboush area ranged between (6.66 to 3261.06 nGy/h) and (6.66 to 46.35 nGy/h) respectively with an average of (386.56 and 16.93 nGy/h) respectively which is higher than the average world limit of (70 nGy/h) in Ramlet Homayier area [25].

The indoor AED in Ramlet Homayier and Heboush area ranged between (0.03 to 16.06 mSv) and (0.03 to 0.23 mSv) respectively with an average of (1.90 and 0.08 mSv) respectively which is higher than the average world limit of (0.5 mSv) in Ramlet Homayier area [11] This can result in health hazard effects due to exposures to such doses that arise from surface abundance of NORM in Ramlet Homayier area, figure (7) and (8).

The outdoor AED in Ramlet Homayier and Heboush area ranged between (0.01 to 4.0 mSv) and (0.01 to 0.06 mSv) with an average of (0.47 and 0.02 mSv) respectively which is lower than the average world limit of (0.5 mSv) for both locations [11]. This can result in negligible effect of health hazard due to exposures to such doses that arise from surface abundance of NORM, figure (7) and (8).

The radium equivalent in Ramlet Homayier and Heboush area ranged between (14.05 to 7041.55 Bq/Kg) and (14.05 to 100.76 Bq/Kg) with an average of (839.31 and 37.49 Bq/Kg) respectively which is higher than the average world limit of (370 Bq/Kg) for Ramlet Homayier area [16]. This gives a sign of not using rocks from Ramlet Homayier area as a building material.

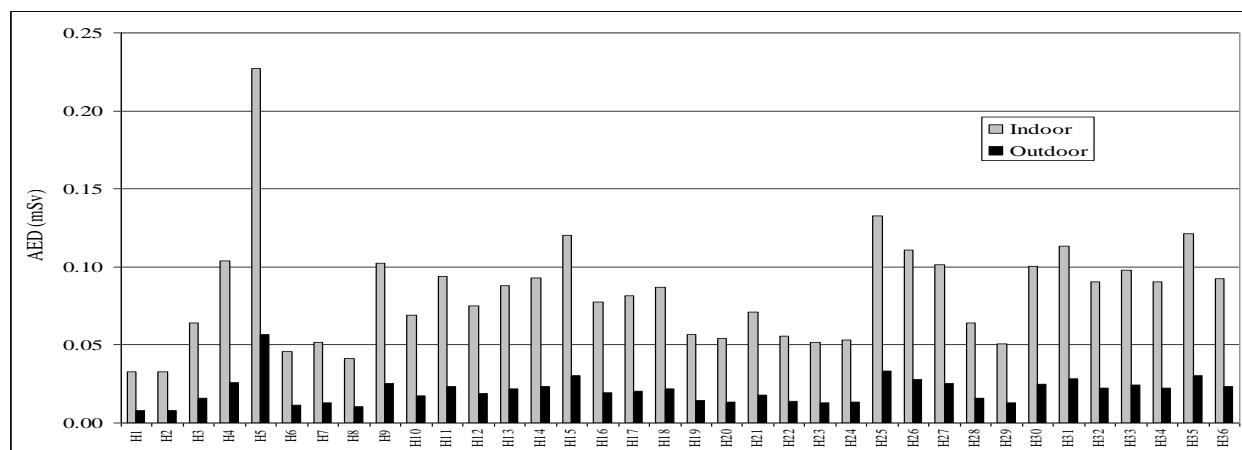


Fig. (7) Indoor and outdoor AEDE for all selected stations in Heboush area

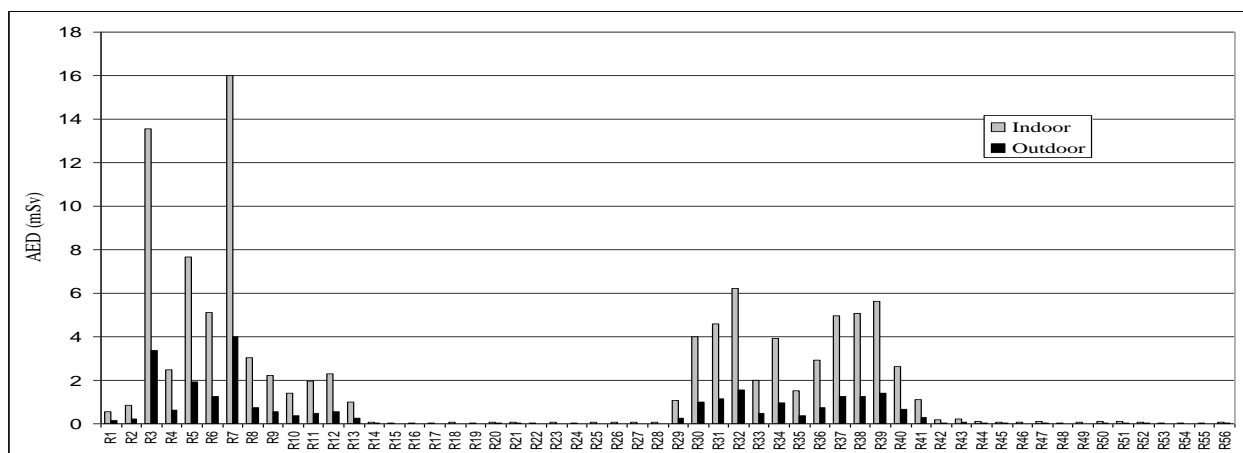


Fig. (8) AEDE for all selected stations in Ramlet Homayier area

5. Hazard indices and ELCR calculations

Table (5) External hazard, internal hazard, index I_{γ} and excess life time cancer risk of selected stations in Heboush and Ramlet Homayier areas

No.	$H_{(ex)}$	$H_{(in)}$	Index I_{γ}	ELCR
Heboush area				
Min.	0.04	0.07	0.1	0.000029
Max.	0.27	0.51	0.68	0.000199
Avg.	0.10	0.15	0.26	0.000073
Ramlet Homayier area				
Min.	0.04	0.13	0.1	0.000029
Max.	19.03	34.99	48.05	0.013998
Avg.	2.27	3.94	5.65	0.001659

Table (5) show the external hazard index in Ramlet Homayier and Heboush area ranged between (0.04 to 19.03) and (0.04 to 0.27) with an average of (2.27 and 0.10) respectively which is higher than unity (1) for Ramlet Homayier area [26].

The internal hazard index in Ramlet Homayier and Heboush area ranged between (0.13 to 34.99) and (0.07 to 0.51) with an average of (3.94 and 0.15) respectively which is which is higher than unity (1) for Ramlet Homayier area [26].

The gamma index in Ramlet Homayier and Heboush area ranged between (0.1 to 48.05) and (0.1 to 0.68) with an average of (5.65 and 0.26) respectively which is higher than the world average of (≤ 1) for Ramlet Homayier area [25].

The excess life time cancer risk in Ramlet Homayier and Heboush area ranged between (0.000029 to 0.013998) and (0.000029 to 0.000199) with an average of (0.001659 and 0.000073) respectively which is higher than the standard probability of (0.00029) for Ramlet Homayier area [22], this reveals the inadequacy of Ramlet Homayier area as a public residence area.

6. Annual effective dose delivered to each body tissue

The annual effective dose for each tissue is calculated from outdoor AED in Ramlit Homayier for both radon concentration from closed cup technique and radiometric measurements and indoor AED Heboush area for both radon concentration from closed cup technique and radiometric measurements and compared to the world maximum tissue dose limit for public and occupation using the tissue weighing factor for the all the tissues.

Table (6) Radon gas and radiometric AED for each tissue in Ramlit Homayier and Heboush area compared to the annual limits for each tissue

	Ramlet Homayier	Heboush area	Ramlet Homayier	Heboush area	Tissue dose limits (mSv)	
	AED from radon gas results (mSv)		AED from radiometric results (mSv)		Pub.	Occ.
Indoor AED	-	19.7	-	0.08	1	50
Outdoor AED	24.71	-	0.47	-		
Gonads	4.94	3.94	0.094	0.016	0.2	10
Bone marrow, Lung, Colon and Stomach	2.96	2.36	0.056	0.0096	0.12	6
Urinary bladder, Liver, Breast, Thyroid gland and Oesophagus	1.23	0.98	0.023	0.004	0.05	2.5
Skin	0.247	0.197	0.0047	0.008	50	500
Bone surface	0.247	0.197	0.0047	0.008	0.01	0.5
Others	1.23	0.985	0.0235	0.004	0.05	2.5

The listed results from table (6) reveals a high dose risk to public derived from the exposure to subsurface NORM in Ramlet Homayier more than Heboush area for most body tissues especially in closed areas when there will be poor or insufficient ventilation and is delivered most to gonads and abdominal organs (digestive, respiratory and reproductive systems) for being there in the two locations around the 24 hours either in staying in homes or doing grazing activities. However if compared to the occupational limits it shows lower risk; on the other hand a low dose risk arise from the surface exposure to NORM in both locations. Finally applying the same daily habits requires the implementation of radiation protection principals and considering workers in Ramlet Homayier area occupational workers.

Finally, the great difference between dose delivered by NORM (surface) and cup technique (subsurface) may be attributed to, the mechanism of measurements, where in (surface) depends mainly upon γ -ray emitted from long lived nuclei, while in case of (subsurface) cup techniques it depends on the α -particles with specific energy emitted from ^{238}U as a parent nuclei for ^{226}Ra and ^{222}Rn .

Conclusions

According to the γ -ray spectrometric survey, Heboush area show low eU-content ranging from 0.7 ppm to 4.4 ppm this may be attributed to that Heboush area was covered by a very thick layer of barren sand. The average eU/eTh ratio of the most measured stations is 2.47 indicating the addition of uranium (migration in). While Ramlet Homyier area was covered by a very thin layer of sand in which you can reach to the lower member of Um Bogma Formation after a few centimeters. Ramlet Homyier area reaches more than 2300 ppm eU-content. The average eU/eTh ratio of the area is 12.99 indicating an addition of uranium (migration in).

This research work provides baseline data for NORM concentration in Ramlet Homyier and Heboush areas located in south western Sinai, the specific activity concentrations of ^{238}U , ^{232}Th , ^{226}Ra and ^{40}K with the radon gas concentrations gives a complete view of the radiological health hazards that public citizens are subjected to due to their daily activities either indoor or outdoor and whether its external or internal exposures. It is recommended according to this paper that staying in such levels of NORM requires a high caution and awareness to minimize the health risk accompanied to daily exposure of public and applying radiation protection principals to achieve a better safe working and living environment.

The results obtained from this research is useful for establishing a data baseline of background radiation levels in the selected area, and represent a basis to assess any further changes in the radioactivity background levels due to various geological processes or any artificial influences around the area under considerations.

The Authors declare that there is no conflict of interest.

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