Natural Radioactivity Measurements of Basalt Rocks in Wadi Khuda Area, Southwest of Safaga, Eastern Desert of Egypt

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--*ABSTRACT*--
By using gamma spectrometry NaI(Tl) "3×3", the concentrations of (^{226}Ra, ^{232}Th and ^{40}K) were measured and its radiological hazards were presented in this paper for some basalt rock samples collected from Wadi Khuda Area Southwest of Safaga,Eastern Desert of Egypt. The ranges of concentration levels of ^{226}Ra, ^{232}Th and ^{40}K were (4.29±0.22to 64.39±2.52) BqKg^{-1}, (7.49±0.45to 39.27±2.40)BqKg^{-1}and (283.24±24.36to1709.12±147.024)BqKg^{-1}, respectively.In the other side, the range values obtained from basalt rock under investigation were (47.22to216.23BqKg^{-1}), (0.2to 0.8), (0.1 to 0.6),(0.4 to1.7), (23.63 to107.54 nGyh^{-1}),(115.93 to527.58μSvy^{-1}), (28.98to131.89μSvy^{-1}),for radium equivalent activity, internal hazard index (H_{in}), external hazard index (H_{ex}),representative level index I_{yr}, Dose rate (nGyh^{-1}),indoor and outdoorAnnual effective dose (AED) in the air,respectively, due to gamma radiation and the annual gonadal dose equivalent (AGDE) were calculated , it was lowerthe world average value 300μSv y^{-1}. The excess lifetime cancer risk (ELCR) have been calculated, its values were higher than the world's average value of (0.29x 10^{-3}). The average results obtained in this study are lower than the average national and world recommended values; therefore, there is no health risk to the populace of the area.
Keywords: Absorbed dose, activity concentration, igneous rocks, Eastern Desert of Egypt, cancer risk.

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I. INTRODUCTION

We live with radiation every day and everywhere. Wherever we are, whenever we are, we will be in natural radioactive zone. The air we breathe, the food we eat, the drinks we drink even we ourselves are containing natural radioactive materials[1]. Natural radiations originate from many sources, including more than 60 naturally occurring radioactive materials found in rock, soil, water, and air. The maximum contributions to these invisible radiations originate from the decay series of ^{238}U, ^{232}Th and the singly occurring isotopes like ^{40}K[2].Distribution of naturally occurring radionuclides mainly ^{238}U, ^{232}Th and ^{40}K and other radioactive elements depends on the distribution of rocks from which they originate and on the processes through which they are concentrated[3].Radium and its ultimate precursor uranium in the ground are the source of radon and α-radioactive inert gas. As an inert gas and having sufficiently long lifetime (3.8 days) it can move freely through the materials like rock, soil, sand, etc. Short lived radon progenies have been established as causative agents of lung cancer. Radon appears when radium (^{226}Ra) -^{238}U-family division Product – splits up[4]**.** Potassium is a major element widely distributed in crustal rocks, for instance, calcium rich granites may contain up to 2.5% K. ^{40}K is the only radioactive isotope of potassium and is present inanamountof0.0119%in this natural element^{40}K decays directly to ^{40}Ca in the ground state through β - emission (89.3%)and also to ^{40}Ar ina1.46MeV excited state followed by a prompt 1.46MeVgamma emission through electron capture. The radioactive elements of various radionuclides in rocks may affect the health. Thus, numerous studies have been performed in many regions of the world, and the obtained data can be used to establish if the local controls are needed [5].The collected samples are igneous rocks of extrusive and Basalt types and composed of the major minerals (Pyroxene, Calcium-rich Plagioclase Field spars and Olivine) [6].In the last decades, there has been a growing concern with the natural radioactivity of the rocks mainly due to the significant increase in the number of buildings coated internally by these materials. Such aspects and the fact that many of them constitute closed environments and with restricted air circulation have caused health concerns as elevation of toxicity risk in these places can occur[7]**.**Thus, this paper aims to contribute to a better understanding of the radioactivity distribution in igneous rocks provided fromdistinct genetic environments and that are commonly used as ornamental and for surfacing.

II. MATERIALS AND METHODS

2.1. Sample collection and preparation:

A total of 21 basalt samples were collected randomly from Wadi Khuda Area Southwest of Safaga, Eastern Desert of Egypt**Fig. 1**. The masses of the collected samples varied between 350 and400gm. Each sample was dried in an oven at about 110°Cto ensure that moisture was completely removed,the samples were crushed, homogenized and sieved through a 200μmmesh, which is the optimum size enriched in heavy minerals. Weighed samples were placed in a standard plastic container (7.5 x 5.5 cm), and after property tightening the threatened lid, the containers were sealed with adhesive tape and left for at least 4 weeks to reach secular equilibrium where the rate of decay ofthe progeny becomes equal to that of the parent (radium and thorium).This step is necessary to ensure that radon gas confined within the volume and the progeny will also remain in the sample[8],[9].
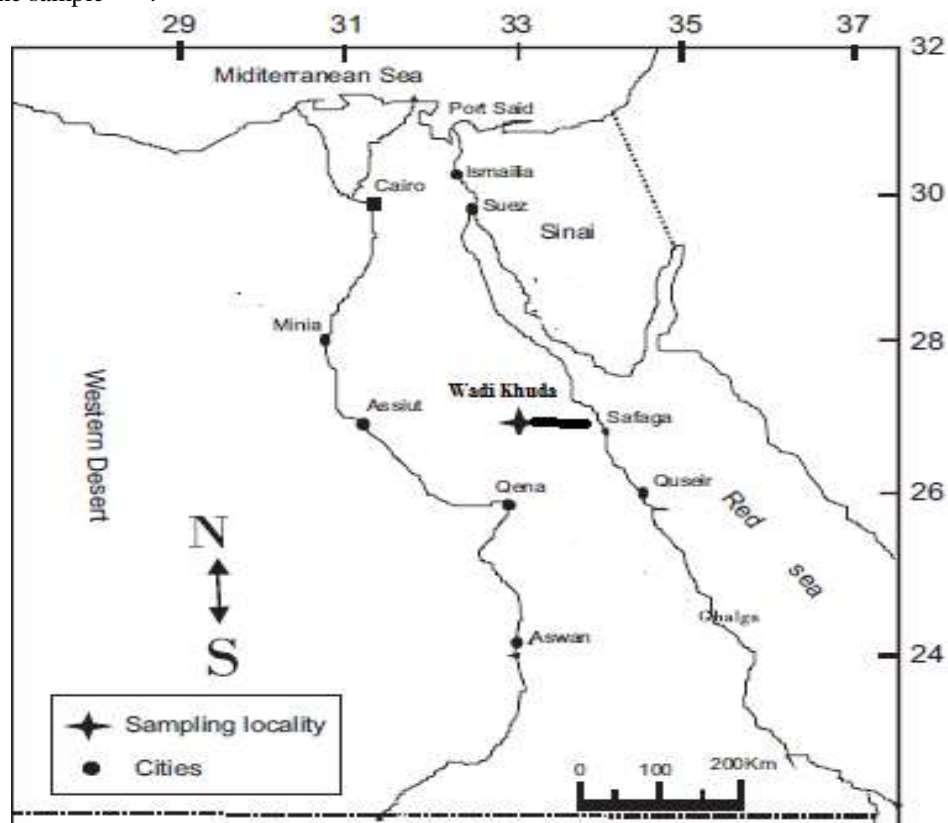

Fig. 1: Map of the investigated area, WadiKhuda Area Southwest of Safaga, Eastern Desert of Egypt.

2.2. Calculation of Elemental Concentration

Activity measurements were carried out using NaI(Tl) detector. It consists basically of 3×3 inch NaI (Tl), S-1212-I model, with a 1024 microcomputer multichannel analyzer, 5510 OrtecNorland. The applied detector has a peak gamma ray efficiency of $2.3×10^{-2}$ at 1332 keV, energy resolution of 7.5% at 662 keV and operation bias voltage 805 Vdc. The detector was housed inside a massive cylindrical lead shield with quarter 25cm to reduce the background radiation. The detector is connected to preamplifier, main amplifier, analogue to digital converted (ADC) and multichannel analyzer. The system was calibrated for energy using standard point sources (^{60}Co, ^{137}Cs), and calibrated for efficiency using standard QCYB41. Every sample was placed in face to face geometry the detector for 10 to 24 hour for (^{226}Ra, ^{232}Th and ^{40}K) concentrations measurements. The resultant spectrum of each sample was acquired via the Genie 2000 software package. Prior to sampling counting, background were taken normally every week under the same condition of sample measurement[10].The^{226}Ra radionuclide was estimated from the351.9 keV (35.1%) γ -peak of ^{214}Pb, and at 609.32 keV (44.6%) of ^{214}Bi. The 186 keV photon peak of ^{226}Ra was not used because of the interfering peak of ^{235}U, with energy of 185.7 keV. ^{232}Th was determined using gamma-energies at 911.16 keV (26.6%) of ^{228}Ac and at 2614 keV (35.8 %) of ^{208}Tl.

The ^{40}K radionuclide was estimated using the 1461 keV γ -peak from ^{40}K itself [11].The specific activity (in Bq·kg^{-1}), $A_{Ei}$of a nuclide *i*. and for a peak at energy *E*,is given by:

$$A_{Ei} = \frac{NP}{t_c \times I_\gamma(E_\gamma) \times \varepsilon(E_\gamma) \times M} \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where NP is the number of count in a given peak area corrected for background peaks of a peak at energy $E, \varepsilon(E_\gamma)$ the detection efficiency at energy E, t_c is the counting life time, $I_\gamma(E_\gamma)$ the number of gammas per disintegration of this nuclide for a transition at energy E, and M the mass in kg of the measured sample[12][35].

2.3. Evaluation of radiological hazard effects:
2.3.1. Radium equivalent activity:
In order to compare the activity concentration of basalt igneous rocks samples, which contain ^{226}Ra, ^{232}Th and ^{40}K the radium equivalent activity as a common index was used to obtain the sum of activities. The radium equivalent activities Ra_{eq} have been calculated on the estimation that 370 Bqkg^{-1} of ^{226}Ra, 259 Bqkg^{-1} of ^{232}Th and 4810 Bqkg^{-1} of ^{40}K produce the same gamma ray dose rateTherefore, the Ra_{eq} is given by[13], [14], [15]:
Ra_{eq} (Bq.Kg^{-1}) = A_{Ra} +1.43A_{Th} +0.077A_K (3)
Where A_{Ra}, A_{Th}, and A_K, are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively[7], [16].

2.3.2. Absorbed dose rate (D):
The absorbed dose rates (D) due to gamma radiations in air at 1m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) were calculated based on guide lines provided by (UNSCEAR;2000).The conversion factors used to compute absorbed gamma dose rate (D) in air per unit activity concentration in Bqkg^{-1} (dry weight) corresponds to 0.462 nGyh^{-1} for ^{226}Ra, 0.604 nGyh^{-1} for ^{232}Th and 0.042 nGyh^{-1} for ^{40}K.Therefore D can calculate as follows[17], [18], [11]:
D (nGy.h^{-1}) = 0.462A_{Ra} + 0.604A_{Th} + 0.042A_K (4)
Where A_{Ra}, A_{Th}, and A_K having the same meaning as in Eq. (3).

2.3.3. Annual effective dose equivalent (AEDE):
To estimate the annual effective dose equivalent, the conversion coefficient from absorbed dose (D) in air to effective dose, 0.7 SvGy^{-1} was used for the conversion coefficient from absorbed dose in air to effective dose received by adults, and 0.8 for the indoor occupancy factor and implying that 20% of time is spent outdoors, outdoor occupancy factor of 0.2 Proposed by UNSCEAR 2000 were used [19] [24].The Annual effective dose equivalent (AEDE) in units of mSvy^{-1}was calculated by the following formulae[14]:
Indoor Annual effective dose equivalent (AEDE):
AEDE (μ Sv y^{-1}) = D (nGy h^{-1}) x 8760 h x 0.8 x 0.7 SvGy^{-1} x 10^{-6} (5)
Outdoor Annual effective dose equivalent (AEDE):
AEDE (μ Sv y^{-1}) = D (nGy h^{-1}) x 8760 h x 0.2 x 0.7 SvGy^{-1} x 10^{-6} (6)

2.3. Hazard indices:
A widely used hazard index (reflecting the external exposure) called the external hazard index H_{ex} is defined as follows[20]:
H_{ex} = (A_{Ra}/370 + A_{Th}/259 + A_K/4810) $\leq$ 1 (7)
Where A_{Ra}, A_{Th}, and A_K having the same meaning as in Eq. (3).
In addition to external hazard index, radon and its short lived products are also hazardous to the respiratory organs.
The internal exposure to radon and its daughter product is quantified by the internal hazard index H_{in}, which is given by:
H_{in}= (A_{Ra}/185 + A_{Th}/259 + A_K/4810) $\leq$ 1 (8)
The values of the indices (H_{in}, H_{ex}) must be less than unity ($\leq$1) for the radiation hazard to be negligible.From table (4) we can see that the values of the External hazard index, H_{ex} for the basalt rock samples studied in this work ranged from 0.127 to 0.584 with an average value of 0.285, the computed internal hazard index H_{in} values vary from 0.154 to 0.758 with an average value of 0.360.
The average values of H_{ex} and H_{in} of all samples studied in this work were less than unity, which are acceptable global values [11], [21].

2.4. Representative level index ($I_{\gamma r}$):
The representative level index, $I_{\gamma r}$, used to estimate the level of γ- radiation hazard associated with the natural radionuclides in specific investigated samples, is defined from the following Equation:

$$I_{\gamma r} = (A_{Ra}/150 + A_{Th}/100 + A_K/1500) \qquad\qquad (9)$$

Where A_{Ra}, A_{Th}, and A_K having the same meaning as in Eq. (3).
From table (4) we can see that the values of representative level index for the studied samples in this work ranging from 0.372 to 1.67 with an average value of 0.808.The $I_{\gamma r}$ values are lower than the internationally accepted value 1[1],[12],[22].

2.5. Annual gonadal dose equivalent:
The annual gonadal dose equivalent (AGDE) due to the specific activities of ^{226}Ra, ^{232}Th, and ^{40}K was calculated using the following formula [3], [23],[24]:

$$\text{AGDE } (\mu Sv\ year^{-1}) = 3.09A_{Ra}+4.18A_{Th}+0.314A_K \qquad (10)$$

Where A_{Ra}, A_{Th}, and A_K having the same meaning as in Eq. (3).

2.6. Excess lifetime cancer risk (ELCR):
Excess lifetime cancer risk (ELCR) was calculated by using the following equation:

$$\text{ELCR} = \text{AEDE} \times DL \times RF \qquad\qquad (11)$$

Where DL is duration of life (70 year) and RF is risk factor (Sv^{-1}) fatal cancer risk per Sievert. For stochastic effects, [ICRP 60] uses values of 0.05 for the public [1], [36].

III.   RESULT AND DISCUSSION
The Activity concentrations in ($BqKg^{-1}$) as well as the uncertainty for the twenty one basalt rock samples calculated for each of the^{226}Ra, ^{232}Th and ^{40}K radionuclides by using equation (1), are listed in table (1), and shown in Figure (2)respectively. The obtained results, in table (1), showing that the values of the measured specific gamma ray activities (Bq kg^{-1}) in basalt rock samples as follows: for ^{226}Ra the activity concentrations are ranged from 4.29 ± 0.22 in sample $R_3$to 64.39 ± 2.52 $BqKg^{-1}$in sample $R_{15}$with an average (mean) value of, 28.05 ± 1.93 $BqKg^{-1}$whereas the activity concentration values of ^{232}Th are between 7.48 ± 0.45 in sample R_7 to 39.27 ± 2.40 $BqKg^{-1}$ in sample R_{17} with an average (mean) value of20.20 ± 0.86 $BqKg^{-1}$. The ^{40}K activity concentrations ranged between 283.24 ± 24.36in sample $R_{19}$and 1709.12 ± 147.024 $BqKg^{-1}$in sample $R_{13}$with an average (mean) value of 628.76 ± 54.08 $BqKg^{-1}$.The mean activity concentration values for ^{226}Ra and, ^{232}Th were lower than the recommended radioactivity levels of 50, 50 as reported by UNSCEAR 2000, while ^{40}K mean concentration was found to be greater than the global value 500 $Bq \cdot kg^{-1}$.The range of lowest(minimum), highest (maximum) and average values of the activity concentration of the natural radionuclides in each area are given in table (1) and shown in fig. (3).The high activity concentration of ^{40}K in some rock samples may be attributed to the presence of relatively increased amount of accessory minerals such as zircon, iron oxides, fluorite and other radioactive related minerals [25][26].The comparison between the specific activity of ^{226}Ra, ^{232}Th and ^{40}K for basalt rock sampleswith other regions of the world was listed in table (2). This comparison is also illustrated in Fig. (5)As shown in this table, the radioactivity in rock samples varied from one country to anotherdepends on the locality geological conditions[27] [28] [29].The values of concentration followed by contents of concentration in % for ^{40}K and in ppm for ^{232}Th and ^{226}Ra (^{238}U) are shown in Table 3. Fig. (4) Shows the contents of each radionuclide. To obtain uranium concentration content in these rock samples, the value of ^{238}U concentrations in ppm were calculated using (1 ppm U $=12.25$ $BqKg^{-1238}$U) the concentration contents of ^{238}U is ranged from 0.343 to 5.15 ppm with an average value of 2.24 ppm as shown in Table 3.The value of ^{232}Th concentration in ppm was calculated using 1ppm Th $= 4.10$ $BqKg^{-1232}$Th [20],[30],. The concentration of ^{232}Th is ranged from 1.82 to 9.58 ppm with an average value of 4.93 ppm as shown in Table 3. The value of ^{40}K activity concentrations ranged between (283.24 ± 24.36) and (1709.12 ± 147.024) $BqKg^{-1}$ with an average (mean) value of 628.76 ± 54.08 $BqKg^{-1}$. Table 1, and the concentration of content in percent (%) was calculated ,Concentration content of ^{40}K ranged from 0.88 to 5.31 % with an average value of 1.95% as shown in Table 3.Table(4)summarized the results of the hazard parameters as the following:-

The values of Ra_{eq} for all samples range from 47.22 to 216.23 $Bqkg^{-1}$ with a mean value 105.36 $Bq \cdot kg^{-1}$. These obtained values were below the recommended maximum value of 370 $Bqkg^{-1}$, which is equivalent to an external dose of 1.5$mSvy^{-1}$. Therefore, the rock samples are within an acceptable safe limit. The estimated absorbed dose rate varied from 23.63 to 107.55 $nGyh^{-1}$. The mean absorbed dose rate was calculated to be 51.57 $nGyh^{-1}$ within the typical range of worldwide average values (18 - 93) reported in UNSCEAR 2000.The calculated values of annual effective dose AEDE (outdoor) ranged from 28.98to 131.89μSvy^{-1} with a mean value 63.25$\mu Sv \cdot y^{-1}$and annual effective dose AEDE (indoor) ranged from115.93 to 527.5825μSvy^{-1} with a mean value 252.99μSvy^{-1}.The recommended upper limit of 1 $mSvy^{-1}$ is not exceeded in all samples. This means that these rock samples are safety for human health.The external hazard (H_{ex}) in the rock samples ranged from 0.13 to 0.58 with a mean value of 0.28. Also, the internal hazard (H_{in}), its values ranged from 0.15 to 0.76 with a mean value of 0.36. All thesamples had an internal hazard values below the recommended limit of 1.0 which implies that these samples are suitable as interior building materials. In

general, for the safe use of a material in the construction of dwellings, H_{ex} and H_{in} should be less than unity.From table (4) we can see that the values of AGDEis ranged from 170.64 to 771.01μSvy^{-1} with a mean value of368.57 μSvy^{-1}these values is a little higher than the world average values for basalt rock 300 μSvy^{-1}. From table (4) we can see that the values of ELCRare ranged from 0.51 to 2.31 with an average value of1.106x10^{-4} this value is lower than the world's average value of (0.29x10^{-3}).

Table 1: Activity concentration (Bq.Kg^{-1}) of^{238}U, ^{232}Th and ^{40}Kin basalt igneous rocks samples.

Sample Number	Activity concentration (Bq/ kg)		
	^{226}Ra	^{232}Th	^{40}K
R 1	16.25 ± 0.815	16.78 ± 1.04	795.17 ± 68.40
R 2	6.74 ± 0.351	15.51 ± 0.952	694.46 ± 59.74
R 3	4.29 ± 0.225	17.41 ± 1.07	424.44 ± 36.51
R 4	15.56 ± 0.659	14.68 ± 0.904	541.67 ± 46.59
R 5	52.41 ± 2.10	28.92 ± 1.89	660.28 ± 56.80
R 6	27.79 ± 1.10	14.51 ± 0.884	397.47 ± 34.19
R 7	9.68 ± 0.488	7.49 ± 0.457	348.47 ± 29.97
R 8	8.68 ± 0.435	13.44 ± 0.822	344.45 ± 29.63
R 9	20.53 ± 0.876	9.85 ± 0.623	520.44 ± 44.77
R 10	15.32 ± 0.633	16.50 ± 1.01	513.60 ± 44.18
R 11	18.36 ± 0.809	17.20 ± 1.05	341.73 ± 29.39
R 12	14.41 ± 0.555	9.44 ± 0.581	379.53 ± 32.65
R 13	37.79 ± 1.43	26.44 ± 1.84	1709.12 ± 147.02
R 14	55.65 ± 1.84	27.55 ± 1.68	1045.39 ± 89.93
R 15	64.39 ± 2.52	28.54 ± 1.96	1441.81 ± 124.03
R 16	54.71 ± 2.17	27.70 ± 1.85	837.03 ± 72.01
R 17	42.48 ± 1.69	39.27 ± 2.40	614.84 ± 52.89
R 18	30.11 ± 1.19	18.02 ± 1.18	416.01 ± 35.78
R 19	30.14 ± 1.17	21.37 ± 1.31	283.24 ± 24.36
R 20	29.46 ± 1.15	30.72 ± 1.87	466.29 ± 40.11
R 21	34.33 ± 1.34	22.94 ± 1.48	428.53 ± 36.86
Minimum	**4.29 ± 0.225**	**7.49 ± 0.46**	**283.24 ± 24.36**
Maximum	**64.39 ± 2.52**	**39.27 ± 2.40**	**1709.12 ± 147.02**
Mean	**28.05 ± 1.93**	**20.20 ± 0.86**	**628.76 ± 54.08**
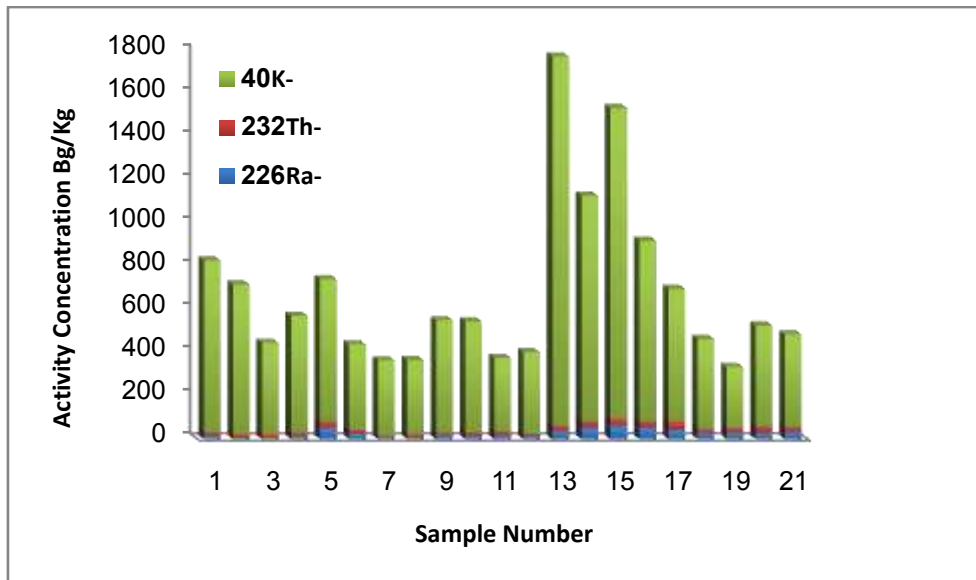
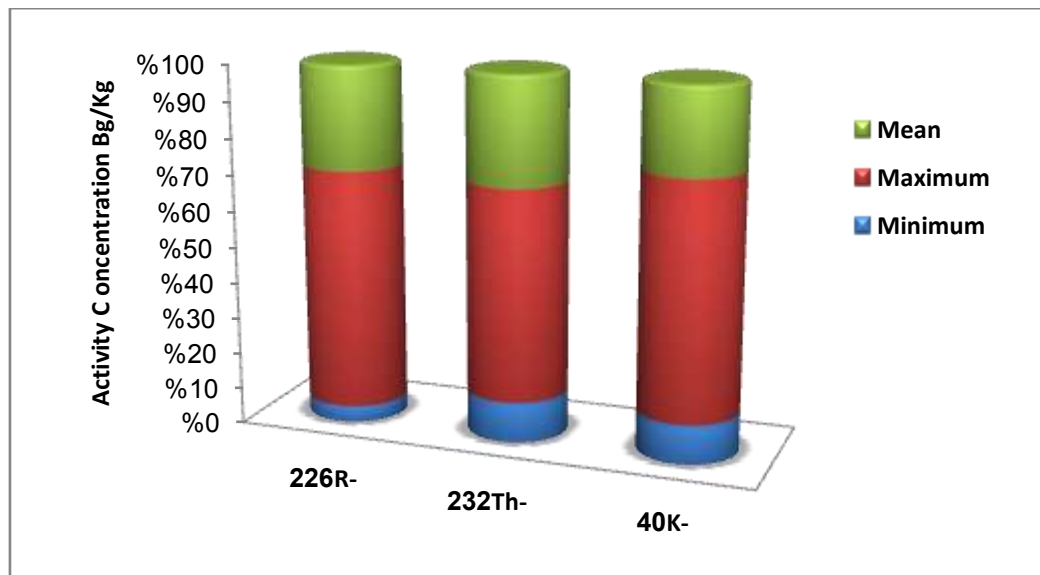**Fig.2:Activity concentration in (Bq.Kg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K.**

Fig.3:The range of lowest (minimum), highest (maximum) and average values of the activity concentration in (BqKg^{-1}) of (^{226}Ra), ^{232}Th and ^{40}K.

Fig. 4:The ^{226}R, ^{232}Th and ^{40}K Content.
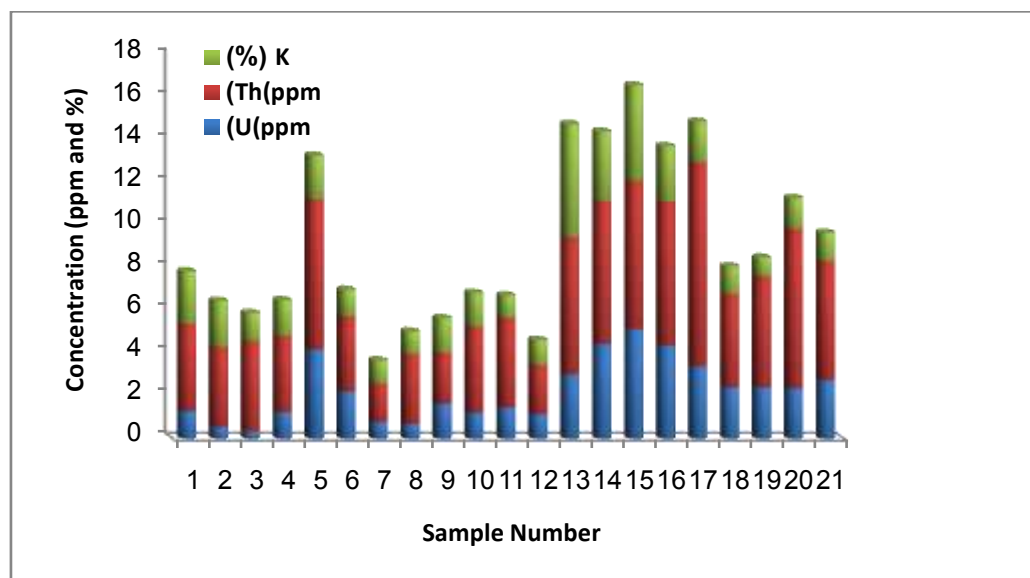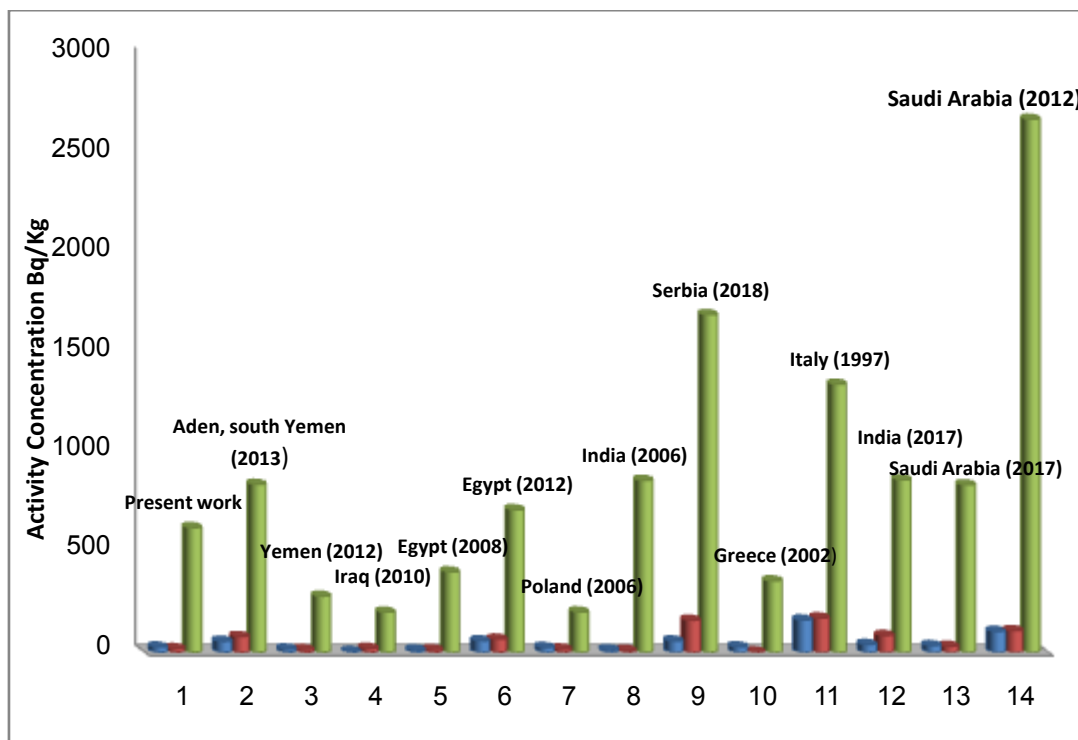
Fig. 5: Comparison of the resulted activity concentration with those of other countries.

Table 2: Comparison of mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in in basalt igneous rocks with those in other countries.

Sample No.	Region	Mean activity concentration (Bq/ kg)			Reference
		^{226}Ra	^{232}Th	^{40}K	
1	Safaga, eastern Desert of Egypt	28.05	20.21	628.76	Present work
2	Serbia, StaraPlanina (2018)	58	163	1700	Sanna et al(2018)[34]
3	Eastern Desert, Egypt (2012)	59.5	67.7	718.5	Harb et al.(2012)[13]
4	Kurdistan, Iraq (2011)	5.65	21.4	203.34	Ali et al (2011).[30]
5	Aden, south Yemen (2013)	57.08	80.26	846.21	Harb et al (2014)[20]
6	Sana'a, Yemen (2012)	18.2	15.1	284	Harb et al (2012)[16]
7	Eastern Desert, Egypt(2012)	61.62	76.18	1385.0	Moura et al. (2011)[7]
8	India (Kaiga) (2006)	14.2	11.5	866.2	Patra et al.(2006)[33]
9	Turkey (2014)	12.01 - 48.95	8.2 - 53.27	143.97- 452.34	Akkurt et al. (2014)[24]
10	Southern Italy (1997)	164	174	1350	Bellia et al.(1997)[13]
11	India (2017)	41.08	86.26	869.29	Prakash et al (2017) [31]
12	Saudi Arabia (2017)	35	31.52	843.63	Al-Zahrani, J. (2017)[25]
13	Saudi Arabia(2012)	106.4	110.35	2683	Hamidalddin, (2012)[32]

Table 3: ^{226}Ra, ^{232}Th and ^{40}K content in samples which are measured by NaI (TI) detector.

Sample Code	Activity concentration (Bq/ kg)		
	U (ppm)	Th (ppm)	K (%)
1	1.300	4.092	2.469
2	0.539	3.781	2.156
3	0.343	4.245	1.318
4	1.245	3.581	1.682
5	4.193	7.053	2.050
6	2.224	3.538	1.234
7	0.775	1.825	1.082
8	0.695	3.278	1.069
9	1.642	2.403	1.616
10	1.225	4.025	1.595
11	1.469	4.196	1.061
12	1.153	2.304	1.178
13	3.024	6.448	5.307
14	4.452	6.722	3.246
15	5.151	6.962	4.477

1	6	4.376	6.757	2.599
1	7	3.398	9.578	1.909
1	8	2.408	4.395	1.292
1	9	2.412	5.213	0.879
2	0	2.356	7.493	1.448
2	1	2.746	5.594	1.331
Minimum		0.343	1.825	0.879
Maximum		5.151	9.578	5.307
Mean		2.244	4.928	1.952

Table 4: radiological hazard for the samples.

Sample No.	Ra_{eq} (Bq.Kg⁻¹)	D(nGyh⁻¹)	AEDE(indoor) (μsvy⁻¹)	AEDE(outdoor) (μsvy⁻¹)	H_{in}	H_{ex}	$I_{\gamma r}$	AGDE (μsvy⁻¹)	ELCR (10⁻⁴)
1	101.47	51.04	250.38	62.59	0.318	0.274	0.806	370.03	1095.4
2	82.39	41.65	204.32	51.08	0.241	0.223	0.663	303.72	893.88
3	61.86	30.32	148.75	37.19	0.178	0.167	0.485	219.29	650.79
4	78.27	38.81	190.39	47.59	0.253	0.211	0.612	279.56	832.96
5	144.60	69.41	340.50	85.12	0.532	0.391	1.08	490.15	1489.69
6	79.15	38.29	187.87	46.97	0.288	0.214	0.595	271.34	821.95
7	47.22	23.63	115.93	28.98	0.154	0.127	0.372	170.64	507.18
8	54.43	26.59	130.48	32.62	0.170	0.147	0.422	191.17	570.84
9	74.69	37.29	182.96	45.74	0.257	0.201	0.582	268.05	800.47
10	78.46	38.62	189.43	47.36	0.253	0.212	0.609	277.58	828.78
11	69.28	33.23	163.01	40.75	0.237	0.187	0.522	235.97	713.18
12	57.14	28.31	138.85	34.71	0.193	0.154	0.443	203.19	607.48
13	207.21	105.21	516.14	129.03	0.662	0.559	1.65	763.97	2258.11
14	175.56	86.26	423.18	105.79	0.624	0.474	1.34	615.42	1851.42
15	216.23	107.55	527.58	131.89	0.758	0.584	1.67	771.01	2308.16
16	158.78	77.17	378.55	94.64	0.576	0.429	1.19	547.69	1656.14
17	145.98	69.17	339.32	84.83	0.509	0.395	1.08	488.48	1484.54
18	87.91	42.27	207.35	51.84	0.319	0.237	0.658	298.98	907.14
19	82.52	38.73	190.01	47.50	0.304	0.223	0.603	271.43	831.29
20	109.30	51.75	253.88	63.47	0.375	0.295	0.814	365.87	1110.71
21	100.13	47.71	234.08	58.52	0.363	0.271	0.744	336.53	1024.08
Mini.	47.22	23.63	115.93	28.98	0.154	0.127	0.372	170.64	507.18
Max.	216.23	107.55	527.58	131.89	0.758	0.584	1.67	771.01	2308.16
Mean	105.36	51.57	252.99	63.25	0.360	0.285	0.808	368.57	1106.86

IV. CONCLUSIONS

The specific activity of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in the basalt igneous rock samples collected from Wadi Khuda Area Southwest of Safaga,Eastern Desert of Egypt were found to be within the average worldwide ranges. Radium equivalent activity Ra_{eq},External hazard index (H_{ex}), Internal hazard index (H_{in}), Absorbed dose rate (D), Annual effective dose equivalent (AEDE), representative level index $I_{\gamma r}$ and Annual gonadal dose equivalent (AGDE) were calculated and found to be within common values , with no significant radiation hazards.The results reported here suggest that most of the igneous rocks can be utilized in closed indoor environments, whereas those exhibiting values of Ra_{eq}> 370 Bqkg⁻¹ and H_{ex}>1 could be employed in outdoor environments and/or indoors with ample ventilation to avoid any risk of human exposure to ^{222}Rn and daughters due to their radiotoxicity. The results can be considered as base values for distribution of natural radionuclides in the region and will be used as reference information to assess any changes in the radioactive background level due to geological processes.

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