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Natural Radioactivity Measurements of Basalt Rocks in Aden governorate, South of Yemen on Gulf of Aden

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Abstract: **The amounts of radioactivity in the igneous rocks have been investigated; 63 basalt rock samples were collected from Aden governorate, south of Yemen. The activity concentration of ^{226}Ra, ^{232}Th and ^{40}K were measured using NaI (TI) detector. Along the study area the radium equivalent activities Ra_{eq} in Bq/Kg of samples under investigation were found in the range of 51.60to 809.26Bq/Kg with an average value of 237.01Bq/Kg, this value is below the internationally accepted value of 370 Bq/Kg. To estimate the health effects of this natural radioactive composition, the average values of absorbed gamma dose rate D (55 nGyh^{-1}), Indoor and outdoor annual effective dose rates E_{ied} (0.11 mSvy^{-1}), and E_{oed} (0.03 mSvy^{-1}), External hazard index H_{ex}(0.138) and internal hazard index H_{in} (0.154), and representative level index $I_{\gamma r}$(0.386) have been calculated and found to be higher than the worldwide average values.**

Keywords: **South Yemen, Absorbed gamma dose, activity concentration, igneous rocks, NaI (TI).**

1. INTRODUCTION

Our world is radioactive and has been since it was created. Over 60 radionuclides can be found in nature. Radionuclides are found in air, water and soil, and additionally in us, being that we are products of our environment. Every day, we ingest/inhale nuclides in the air we breathe, in the food we eat and the water we drink. Radioactivity is common in the rocks and soil that makes up our planet, in the water and oceans, and even in our building materials and homes. It is just everywhere. There is no where on Earth that you can get away from Natural Radioactivity [1, 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]. The main sources of the external γ-radiation are the radionuclides of the U and Th series and ^{40}K [4]. 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 soil, sand, rock etc. Short lived radon progenies have been established as causative agents of lung cancer [3]. Radon appears when radium (^{226}Ra) – ^{238}U-family division Product – splits up. In many countries the most important source of radon is the ground, however, it is possible that radon‘s volumetric activity indoors is determined by building materials, water-supply [5, 6]. Therefore the assessment of gamma radiation dose from natural sources is of particular importance as natural radiation is the largest contributor to the external dose of the world population [2]. Due to the unusual circumstances of Aden and South of Yemen during the last three decades, a limited number of studies exist concerning this important field of investigation. For this the present study has been proposed to cover and establish a base line data for the regional radioactivity. The studied area is located in the Aden Governorate on Gulf of Aden, South of Yemen region, Fig. 1;

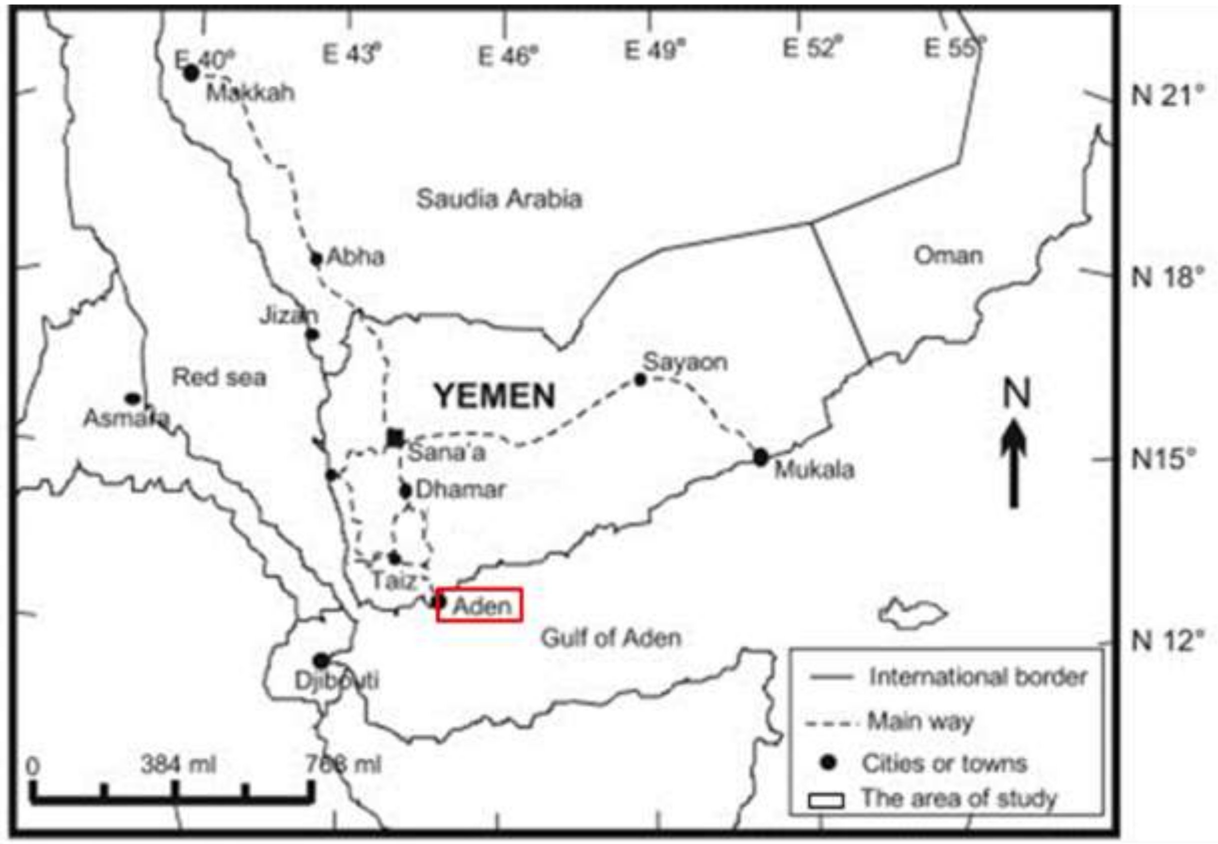

Fig. 1: Location map of the studied area in the Aden Governorate on Gulf of Aden, South of Yemen region [7].

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)[8]. The location of the studied area has been determined using the Global Positioning System (GPS): Latitude: 12°49'.468"N., Longitude: 44°51'.708"E.

2. Materials and methods

2.1Sample collection and preparation:

A total of 63 basalt samples were collected randomly from Aden Governorate on Gulf of Aden, South of Yemen region. The masses of the collected samples varied between 350 and400 gm. The samples were ground and crushed to fine grain size of about 100 meshes to small pieces and sieved in order to homogenize it and remove big size. The samples were then drying at 100^{o}C for 48 h to ensure that moisture is completely removed. The powdered samples were packed 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 before counting by gamma spectrometry in order to ensure that the daughter products of ^{226}Ra up to ^{210}Pb and of ^{232}Th up to ^{208}Pb in secular equilibrium with their respective parent radionuclide and then the gamma ray spectrum was accumulated to up to 900 min.

2.2. Gamma spectroscopic analysis:

To estimate the activity levels of the ^{226}Ra, ^{232}Th and ^{40}K in the samples, a gamma ray spectrometer in Environmental Radioactivity Measurements Laboratory (ERML), physics department, Faculty of Science, University of south valley, Qena, was used in the present investigations. NaI (TI) crystal detector of size 3" X 3" along with an 8K multichannel analyzer was used to record the gamma spectra. The energy calibration of the spectrometer was performed using the 1-l Marinelli calibration sources, which contained well-known standard sources (^{137}Cs, ^{60}Co, ^{57}Co, and ^{241}Am). The absolute efficiency of the detector was determined accurately to evaluate the radionuclide concentrations precisely. This was undertaken using multinuclide standard sources distributed in a sand matrix to be homoconditioned with the investigated soil samples. These standards were obtained from Radioactivity Measurements Laboratory (ERML), physics department, Faculty of Science, University of south valley, Qena. With the counting time of 10,000 seconds for each sample, the below detectable limit (BDL) limits were 21.2Bqkg^{-1} for ^{40}K, 5.5 Bqkg^{-1}for ^{226}Ra and^{232}Th.To determine the radioactivity concentration in the rock samples, each sample was placed on the NaI (TI) detector and counted for the same counting time (12 h). It was found that the detected gamma lines belong to the naturally occurring series radionuclides and a non-series natural radionuclide ^{40}K.

2.3. Activity Concentration

Through calculating the area under the peak (net area) and by means of the detector efficiency curve, the specific activity (activity concentration) A_{Ei} was determined using the formula [9].

$$A_{Ei} = \frac{NP}{t_c . I_\gamma (E_\gamma) . \varepsilon (E_\gamma) . M} \tag{1}$$

Where NP is the number of count in a given peak area corrected for background peaks of a peak at energy E,ε (E_γ) the detection efficiency at energy E, t_c is the counting lifetime,I_γ (Eγ) 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[10].

2.4. Radiation hazard indices:

To represent the activity levels of ^{226}Ra, ^{232}Th and ^{40}Kby a single quantity, which takes into account the radiation hazards associated with them, a common radiological index has been introduced. This index is called radium equivalent (Ra_{eq}) activity and is mathematically defined by [11]:

Ra_{eq} (Bq.Kg^{-1}) = A_{Ra} +1.43A_{Th} +0.077A_K (2)

Where A_{Ra}, A_{Th}, and A_K, are the activity concentrations of^{226}Ra, ^{232}Th and ^{40}K respectively. In the above relation, it has been assumed that 10 Bq/Kg of ^{226}Ra, 7 Bq/Kg of ^{232}Th and130 Bq/Kg of ^{40}K produced equal gamma dose. 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 [11]. We assumed that the contributions from other naturally occurring radionuclides were insignificant. Therefore, D can be calculated according to [11, 13]:

D (nGy.h^{-1}) = 0.462A_{Ra} + 0.621A_{Th} + 0.0417A_K (3)

A widely used hazard index (reflecting the external exposure) called the external hazard index H_{ex} is defined as follows [11]:

$H_{ex} = (A_{Ra}/370 + A_{Th}/259 + A_K/4810) \leq 1$ (4)

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 [11]:

$H_{in} = (A_{Ra}/185 + A_{Th}/259 + A_K/4810) \leq 1$ (5)

The values of the indices (H_{in}, H_{ex}) must be less than unity (≤1) for the radiation hazard to be negligible [11]. To estimate the annual effective dose rates, 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. The effective dose rate (E) in units of mSvy^{-1}was calculated by the following formulae [3]:

Indoor effective dose:

Effective dose rate (m Sv y^{-1}) = D (nGy h^{-1}) x 8760 h x 0.8 x 0.7 SvGy^{-1} x 10^{-6} (6)

Outdoor effective dose:

Effective dose rate (m Sv y^{-1}) = D (nGy h^{-1}) x 8760 h x 0.2 x 0.7 SvGy^{-1} x 10^{-6} (7)

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 [12, 14, 15]:

$I_{\gamma r} = (A_{Ra} /150 + A_{Th}/100 + A_K/1500)$ (8)

3. Result and discussion

3.1. Primordial Radionuclide Activity Concentration:

The Activity concentrations in ($Bq.Kg^{-1}$) for the sixty three studied samples calculated for each of the ^{226}Ra, ^{232}Th and ^{40}K radionuclides by using equation (1) , the results are listed in Table (1) and shown in Fig. (2). the data presented in Table (1) show that radioactive equilibrium between progenies in ^{238}U and ^{232}Th series for all samples can be assumed. Measured rock samples are characterized by values of activity concentrations of ^{232}Th, ^{226}Ra and by high radioactivity of ^{40}K. Calculations of count rates for each detected photo peaks and activity concentration of detected radionuclide depend on the establishment of secular equilibrium in the samples. Since secular equilibrium was reached between ^{232}Th and ^{238}U and their decay products, the ^{232}Th concentration was determined from the average concentrations of ^{228}Ac, ^{212}Pb and that of ^{238}U was determined from the average concentrations of the ^{226}Ra.

The activity concentrations of ^{226}Ra, ^{232}Th as well as ^{40}K, expressed in Bq/Kg. 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 activity concentrations of ^{238}U as estimated on the basis of ^{226}Ra activity concentrations. Activity concentrations of ^{226}Ra ranged from 2.73±0.10 to 216.85±8.4Bq/Kg with an average (mean) value of 57.09±2.12 Bq/Kg. Also the activity concentrations of ^{232}Th in investigated rocks were estimated on the basis of ^{228}Ac and ^{212} Pb activity concentrations. The ^{232}Th activity concentration was ranged from 17.28±1.05 to 286.5±17.55 Bq/Kg with an average value of 80.26±4.8Bq/Kg. Table (2) presents a comparison of the obtained activity concentrations with those calculated in other countries. This comparison is also illustrated in Fig. (5).

The values of concentration followed by contents of concentration in % for ^{40}K and in ppm for ^{232}Th and ^{238}U are shown in Table 3. Fig. (4) Shows the contents of each radionuclide. The higher values of activity concentrations of ^{226}Ra (Bq/Kg), ^{232}Th (Bq/Kg) and ^{40}K (Bq/Kg) are noted in sample 47 (Dhakat Al-kabash*) 216.85±8.36, sample 50 (Labor Island) 286.5±17.5 and sample 47 (Dhakat Al-kabash*) 3747.6±322.4respectively, these two regions located in the middle and down the mountain, while the lower values are noted in samples 31(Gabil Al-oshaq beach)2.73±0.10, 17.28±1.05 and 217.3±18.7 respectively, these sample are from region located in top of the mountain. 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 Bq/Kg ^{238}U) [19], the concentration contents of ^{238}U is ranged from 0.22 to 17.35ppm with an average value of 4.56 ppm as shown in Table 3.

The value of ^{232}Th concentration in ppm was calculated using 1ppm Th = 4.10 Bq/Kg ^{232}Th [19]. The concentration of ^{232}Th is ranged from 4.22 to 69.87ppm with an average value of 19.41 ppm as shown in Table 3. The value of ^{40}K concentrations are ranged from 217.28±18.7to 3747.64±322.4Bq/Kg with an average value of 846.21±72.8Bq/Kg, Table 2, and the concentration of content in percent (%) was calculated , Concentration content of ^{40}K ranged from 0.43to 6.76% with an average value of 2.30% as shown in Table 3.

Table 1: Activity concentration ($Bq.Kg^{-1}$) of ^{226}Ra, ^{232}Th and ^{40}Kin basalt igneous rocks which measured by NaI (TI) detector.

S.no	Name of the site	Latitude	Longitude	Activity concentration (Bq/ kg)		
				^{238}U	^{232}Th	^{40}K
1	Regal Round	12°49'.468	44°58'.590	38.1±1.47	47.82±2.91	710.9±61.1
2	Education Round	12°47'.791	45°02'.104	18.42±0.71	49.54±3.01	326.7±28.1
3	Al-Akilstation	12°47'.463	45°02'.267	74.78±2.9	67.73±4.14	972.6±83.6
4	GabilAl-mahkama	12°47'.016	45°02'.434	20.1±0.77	28.35±1.72	255.3±21.9
5	GabilAl-mahkama	12°47'.077	45°02'.497	76.80±2.95	58.93±5.59	947.1±81.5
6	Aden Hospital	12°46'.934	45°02'.392	67.25±2.59	50.92±3.11	424.2±36.5
7	Aden water office	12°46'.815	45°02'.350	63.40±2.45	88.19±5.37	1037.6±89.2
8	Maglastachary	12°46'.886	45°02'.312	20.18±0.77	39.16±2.39	349.1±30.03
9	Puplic Cinema	12°46'.997	45°02'.137	54.67±2.10	49.69±3.02	791.2±68.06

10	Al-subaraty	12°47'.199	45°01'.958	35.51±1.37	45.17±2.75	518.6±44.6
11	Y- company	12°47'.231	45°01'.821	18.07±0.69	17.61±1.07	372.9±32.07
12	Aden Gate	12°47'.284	45°01'.660	88.94±3.43	56.63±3.45	933.7±80.3
13	Aden GateRound	12°47'.319	45°01'.267	114.09±4.39	52.95±3.23	952.1±81.9
14	Malla Road	12°47'.290	45°01'.416	50.59±1.95	53.19±3.24	737.6±63.4
15	Salem Ali Region	12°47'.276	45°01'.645	44.42±1.71	65.99±4.02	602.9±51.8
16	G.Kasarat Aden	12°47'.028	45°01'.388	33.92±1.31	60.65±3.69	612.7±52..7
17	Kasarat Aden*	12°47'.038	45°01'.449	64.15±1.86	65.82±4.01	681.6±58.6
18	G.Sahareg Aden	12°46'.390	45°01'.752	67.11±1.95	60.40±3.68	655.7±56.4
19	G.Sahareg Aden*	12°46'.425	45°01'.685	63.67±1.80	83.24±5.07	677.6±58.3
20	Shaab Al-aidroos	12°46'.428	45°01'.682	31.60±1.22	49.44±3.01	342.6±29.5
21	Seara mountain	12°46'.625	45°02'.927	43.07±1.66	54.79±3.33	1024.9±88.2
22	Seara mountain*	12°46'.770	45°02'.901	44.15±1.70	85.08±5.19	1027.3±88.4
23	Sea Road	12°50'.564	45°00'.233	52.36±2.02	107.83±6.7	415.5±35.7
24	Hojeif Round	12°50'.560	45°00'.231	57.52±2.22	68.59±4.17	799.9±68.8
25	Hojeif Round*	12°47'.538	44°59'.921	44.30±1.71	79.35±4.85	919.9±79.1
26	Ministry of fish	12°47'.507	44°59'.871	43.17±1.67	69.97±4.26	501.9±43.2
27	Al-kaloa	12°46'.935	44°59'.800	42.80±1.65	110.17±6.7	1084.9±93.3
28	Al-kaloa*	12°46'.957	44°59'.813	41.21±1.61	67.50±4.11	838.7±72.1
29	Al-kaloa Gate	12°46'.808	44°59'.931	35.94±1.39	40.27±2.45	350.1±30.1
30	Goldmor Round	12°46'.341	44°59'.807	19.71±0.76	43.76±2.66	262.7±22.6
31	G.Al- oshaq beach	12°46'.038	44°59'.443	2.73±0.10	17.28±1.05	217.3±18.7
32	Goldmor houses	12°46'.438	44°59'.411	24.62±0.95	36.46±2.22	320.4±27.6
33	Al-feel Gulf Gate	12°46'.646	44°58'.764	13.45±0.52	22.47±1.37	238.8±20.5
34	Gibal Hail	12°46'.586	44°58'.956	17.65±0.68	42.92±2.62	603.2±51.9
35	Al-arosa Round	12°46'.598	44°58'.809	24.66±0.95	21.52±1.31	242.7±20.9
36	Gabil Hail*	12°46'.870	44°58'.739	12.65±0.5	35.45±2.16	266.9±22.9
37	GabilAl-bingsar	12°47'.248	44°58'.628	49.51±1.91	60.32±3.68	691.7±59.5
38	Al-bingsar Houses	12°47'.223	44°58'.803	38.34±1.47	88.06±5.35	853.5±73.4
39	Al-tawahy	12°47'.223	44°58'.985	56.86±2.18	66.98±4.07	823.3±70.8
40	Al-tawahy Airport	12°47'.600	44°59'.331	50.06±1.93	58.96±3.59	516.2±44.4
41	Hojaiffish Min.	12°47'.524	44°59'.520	39.73±1.53	91.42±5.57	827.9±71.2
42	AshighAshaak	12°47'.181	45°00'.367	50.08±1.93	51.59±3.14	673.9±57.9
43	Aden Gov. office	12°47'.337	45°01'.087	33.16±1.28	54.13±3.30	917.3±78.9
44	GabilArawst.	12°47'.466	45°01'.535	17.76±0.47	29.65±1.80	303.2±26.1
45	GabilAraw st.*	12°47'.618	45°01'.523	10.75±0.42	33.70±2.05	155.1±13.3
46	DhakatAl-kabash*	12°47'.618	45°01'.468	120.90±4.65	219.9±13.4	2132.0±183.4
47	DhakatAl-kabash*	12°47'.618	45°01'.468	216.85±8.36	212.5±12.9	3747.6±322.4
48	GabilHadeed	12°47'.875	45°01'.430	61.94±2.39	96.26±5.86	678.8±58.4
49	GabilHadeed *	12°48'.233	45°01'.560	18.65±0.72	41.28±2.51	418.4±35.9
50	GabilLabor Island	12°48'.598	45°01'.107	202.03±7.78	286.5±17.5	2511.3±216.0
51	G.Labor Island*	12°48'.355	45°01'.087	101.80±3.92	124.5±7.6	1315.1±113.1
52	Kasarat Little Ad.	12°48'.632	45°01'.428	85.13±3.27	216.9±13.2	1461.6±125.7
53	Kasarat Little Ad.	12°45'.519	44°53'.645	80.47±3.09	166.6±10.1	1112.9±95.7
54	G.Oil airport Mon.	12°45'.667	45°53'.641	33.21±1.28	123.3±7.5	767.03±65.9
55	Gabil Al-maharak	12°44'.842	44°54'.099	96.19±3.70	149.1±9.1	1574.5±135.4
56	Gabil Al-maharak	12°44'.895	44°54'.148	94.66±3.64	146.8±8.9	2033.4±174.9
57	Gabil Al-hisa	12°44'.947	44°54'.582	130.28±5.02	111.7±6.8	1283.0±110.3
58	Gabil Barbra	12°44'.805	44°54'.861	49.67±1.92	99.59±6.08	1140.1±98.07
59	Gabilsahareeg	12°45'.252	44°54'.378	47.08±1.82	43.64±2.66	685.4±58.9
60	Al-masafy hospital	12°44'.406	44°53'.028	27.40±1.06	39.86±2.43	397.6±34.20
61	Gabil Al-Kadeer	12°43'.988	45°53'.091	64.48±1.85	98.92±6.04	779.1±67.02

62	Gabil Al-masafy	12°44'.502	44°52'.427	196.51±5.51	268.9±16.4	2646.1±227.6
63	GabilRas-Amran	12°44'.715	44°51'.708	53.74±2.074	36.50±2.22	904.65±77.82
		Minimum		**2.73±0.10**	**17.28±1.05**	**217.3±18.7**
		Maximum		**216.85±8.4**	**286.5±17.5**	**3747.6±322.4**
		Mean Value		**57.09±2.12**	**80.26±4.8**	**846.21±72.8**

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

Sl.no	**Location**	**Mean activity concentration (Bq/ kg)**			**Reference**
		^{238}**U**	^{232}**Th**	^{40}**K**	
1	Aden, south Yemen (2013)	57.086	80.26	846.21	Present work
2	Sana'a, Yemen (2012)	18.2	15.1	284	Harb, et al (2012)
3	Kurdistan, Iraq (2010)	5.65	21.4	203.34	UNSCEAR2000
4	Egypt (2008)	13.72	14.46	405.73	Uosif et al (2008)
5	Poland (2006)	25.41	18.1	204.2	Harb (2008)
6	India (Kaiga) (2006)	14.2	11.5	866.2	Patra et al.(2006)
7	Kenya (2004)	18.66	18.7	401.7	UNSCEAR2000
8	Greece (2002)	29	3	361	Al-Azmi (2002)
9	Southern Italy (1997)	164	174	1350	Bellia et al.(1997)

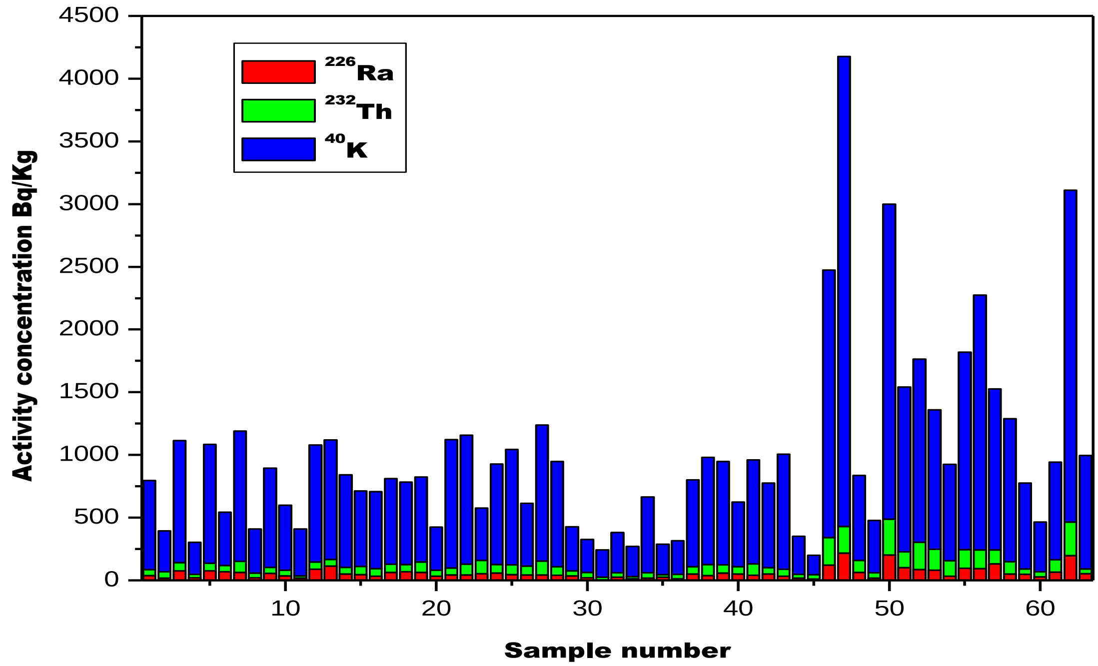

Fig.2: Activity concentration in (Bq/Kg) of (^{226}Ra), ^{232}Th and ^{40}K.

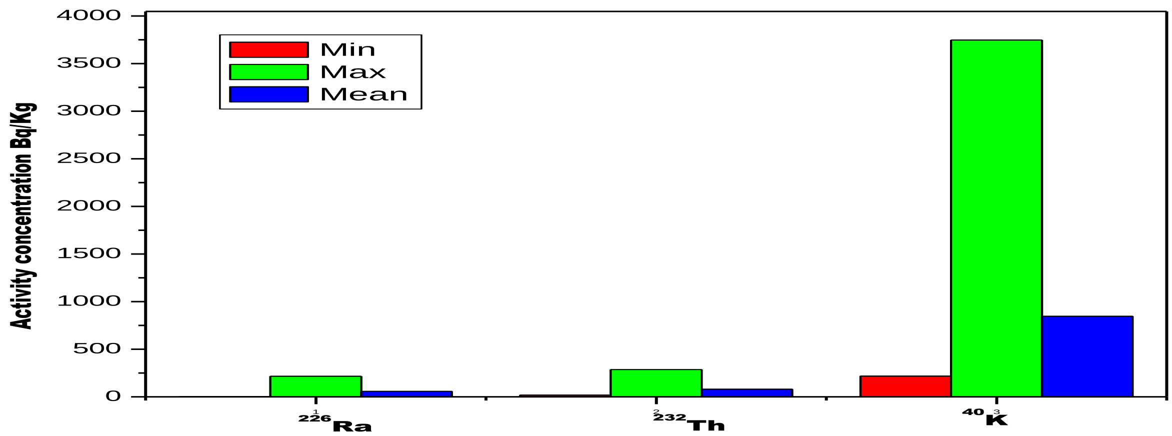

Fig.3: Activity concentration in (Bq/Kg) of (^{226}Ra), ^{232}Th and ^{40}K

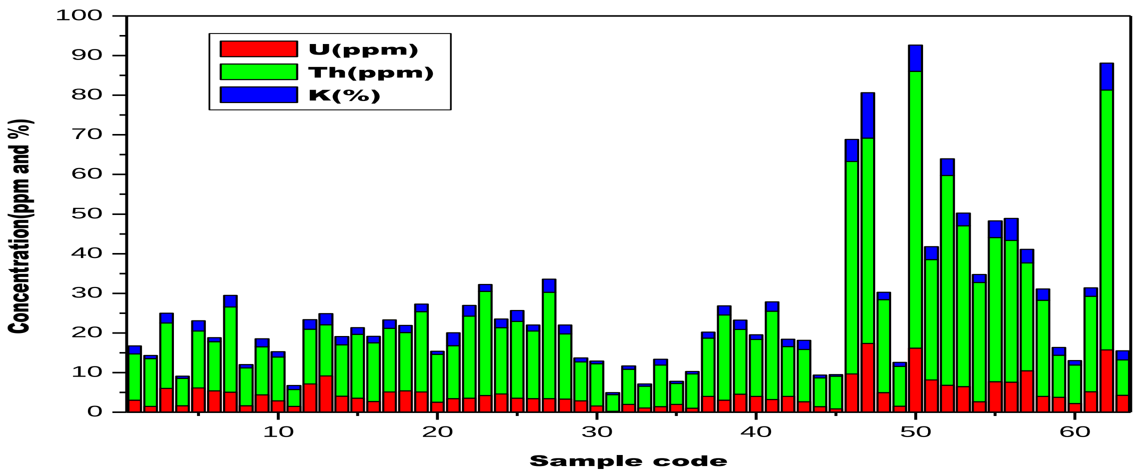

Fig. 4: The^{238}U, ^{232}Th and ^{40}K Content.

Table 3: ^{238}U, ^{232}Th and^{40}K content in samples which are measured by NaI (TI) detector.

Sample Code	Activity concentration (Bq/ kg)				Sample Code	Activity concentration (Bq/ kg)		
	U(ppm)	Th(ppm)	K (%)			U(ppm)	Th(ppm)	K (%)
1	3.04	11.66	2.01		33	1.07	5.48	0.59
2	1.47	12.08	0.74		34	1.41	10.47	1.49
3	5.98	16.52	2.48		35	1.97	5.25	0.59
4	1.61	6.91	0.60		36	1.01	8.65	0.62
5	6.14	14.37	2.59		37	3.96	14.71	1.54
6	5.38	12.42	0.99		38	3.06	21.48	2.29
7	5.07	21.51	2.88		39	4.55	16.34	2.34
8	1.61	9.55	0.88		40	4.00	14.38	1.17
9	4.37	12.12	2.06		41	3.18	22.29	2.36
10	2.84	11.07	1.34		42	4.00	12.58	1.82

11	1.45	4.29	0.97		43	2.65	13.20	2.30
12	7.11	13.81	2.43		44	1.42	7.23	0.74
13	9.13	12.91	2.83		45	0.86	8.22	0.48
14	4.04	12.97	2.06		46	9.67	53.63	5.56
15	3.55	16.09	1.67		47	17.35	51.82	11.46
16	2.71	14.79	1.64		48	4.95	23.48	1.84
17	5.13	16.05	2.13		49	1.49	10.07	1.00
18	5.37	14.73	1.79		50	16.16	69.87	6.62
19	5.09	20.30	1.88		51	8.14	30.37	3.26
20	2.53	12.06	0.81		52	6.81	52.91	4.23
21	3.44	13.36	3.26		53	6.43	40.62	3.21
22	3.53	20.75	2.69		54	2.66	30.07	2.02
23	4.19	26.30	1.73		55	7.69	36.36	4.24
24	4.60	16.73	2.18		56	7.57	35.79	5.52
25	3.54	19.35	2.76		57	10.42	27.25	3.45
26	3.45	17.07	1.49		58	3.97	24.29	2.83
27	3.42	26.87	3.29		59	3.76	10.64	1.93
28	3.29	16.46	2.27		60	2.19	9.72	1.09
29	2.87	9.82	0.99		61	5.16	24.12	2.12
30	1.57	10.67	0.69		62	15.72	65.60	6.76
31	0.23	4.21	0.43		63	4.29	8.90	2.31
32	1.97	8.89	0.83		**Mean value**	**4.56**	**19.41**	**2.30**

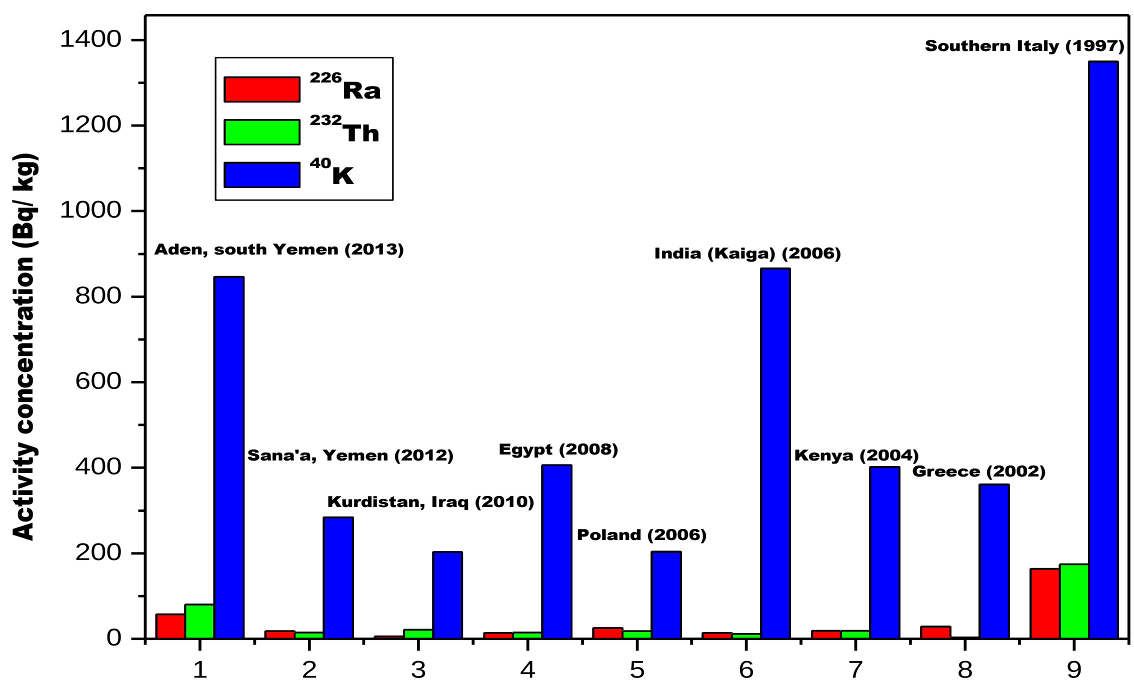

Fig. 5: Comparison of the resulted activity concentration with those of other countries.

3.2. Radiation hazard indices

It is important to assess the gamma radiation hazards to human associated with the used samples for buildings; these were done by calculating the different radiation hazard indices. The radium equivalent activities Ra_{eq} (Bq/Kg) of samples under investigation were calculated on the basis of equation (2) and shown in Table (4), the resulted values ranged from 44.17to 809.259Bq/Kg with an average value of 236.039Bq/Kg, this value is below the internationally accepted value370 Bq/Kg [12]. Along the study area the absorbed dose rate D($nGyh^{-1}$)which expressed in equation (3) ranged from 10.722to 346.073 ($nGyh^{-1}$) with an average value of 110.390$nGyh^{-1}$ these calculated values were higher than the estimate of average global terrestrial radiation of 55 ($nGyh^{-1}$) [12]. Indoor and outdoor annual effective dose rate E_{ied} ($mSvy^{-1}$) and E_{oed}($mSvy^{-1}$) from these basalt rock samples are determined from equations (6) and (7) and ranged from 0.052to 1.697$mSvy^{-1}$with an average value of 0.5415$mSvy^{-1}$ and from 0.025to 0.473$mSvy^{-1}$ with an average value of 0.012$mSvy^{-1}$respectively. The External hazard index and internal hazard index are calculated using equations (4) and (5) the External hazard index, H_{ex} for the basalt rock samples studied in this work ranged from 0.0530to 1.954 with an average value of 0.641, the computed internal hazard index H_{in} values vary from 0.126to2.771with an average value of 0.791. The average values of H_{ex} and H_{in} of all samples studied in this work were less than unity [11], which are acceptable global values. The value of radiation hazard index called the representative level index $I_{\gamma r}$ which expressed in equation (8) must be less than unity for the radiation hazard to be negligible, the value of representative level index for the studied samples in this work ranging from 0.170to 5.50 with an average value of 1.747. The $I_{\gamma r}$ values are higher than the internationally accepted value 1 [12]. The highest and lowest values of Ra_{eq}(Bq/Kg) are noted in sample 47 (Dhakat Al-kabash*) 809.259 and sample 31 (GabilAl-oshaq beach) 44.18, respectively, these two location of samples located to the top and the down of the mountain. The highest values of D ($nGyh^{-1}$), E_{ied}($mSvy^{-1}$) and E_{oed} ($mSvy^{-1}$) are noted in the sample 47 (Dhakat Al-kabash*) 385.92, 1.897 and 0.473respectively,which is located to the middle of the mountain and the lowest values was in sample31 (Gabil Al-oshaq beach) 10.39, 0.05 and 0.012respectively, at top of the mountain. The highest values of H_{ex},H_{in} and $I_{\gamma r}$ are noted in sample 47 (Dhakat Al-kabash*) 1.954, 2.771, and5.503respectively, which is located in the middle of the mountain, while the lowest values is noted in sample 31 (Gabil Al-oshaq beach) 0.119, 0.126, and 0.335respectively, at top of the mountain.

Table 4: The Radium equivalent, absorbed dose rate, Annual effective dose rate, Hazard indices and representative level index of all sites.

Site number	Radiation Hazard indices						
	Ra_{eq} ($Bq.Kg^{-1}$)	**D($nGyh^{-1}$)**	**E_{ied} ($msvy^{-1}$)**	**E_{oed} ($msvy^{-1}$)**	**H_{in}**	**H_{ex}**	**$I_{\gamma r}$**
1	161.13	76.29	0.374	0.093	0.537	0.435	1.205
2	114.42	52.16	0.255	0.063	0.358	0.309	0.836
3	246.54	116.31	0.570	0.142	0.867	0.665	1.824
4	80.28	37.12	0.182	0.045	0.271	0.217	0.587
5	233.99	66.18	0.324	0.135	0.839	0.360	1.048
6	172.73	88.89	0.436	0.097	0.648	0.523	1.384
7	269.42	105.40	0.517	0.154	0.898	0.594	1.649
8	103.07	97.23	0.476	0.058	0.332	0.584	1.537
9	186.66	66.21	0.324	0.108	0.651	0.370	1.0537
10	140.05	77.06	0.378	0.080	0.474	0.447	1.207
11	71.97	59.35	0.291	0.042	0.243	0.347	0.9370
12	241.82	58.20	0.285	0.140	0.893	0.310	0.919
13	263.13	115.28	0.565	0.152	1.019	0.656	1.793
14	183.47	115.68	0.567	0.106	0.632	0.666	1.781
15	185.21	80.83	0.396	0.105	0.620	0.467	1.271
16	167.82	86.11	0.422	0.095	0.544	0.502	1.364
17	210.76	80.93	0.396	0.120	0.742	0.467	1.286

18	203.98	96.94	0.475	0.116	0.732	0.563	1.523
19	234.88	95.94	0.470	0.132	0.806	0.555	1.503
20	128.68	94.08	0.461	0.072	0.432	0.564	1.485
21	200.34	87.51	0.429	0.117	0.657	0.489	1.3883
22	244.93	96.14	0.471	0.140	0.780	0.541	1.519
23	238.55	89.24	0.437	0.130	0.785	0.534	1.422
24	217.22	122.92	0.602	0.124	0.742	0.724	1.960
25	228.61	106.64	0.523	0.131	0.737	0.611	1.682
26	181.88	89.48	0.438	0.102	0.607	0.530	1.423
27	283.88	107.77	0.528	0.161	0.882	0.612	1.710
28	202.32	121.54	0.596	0.116	0.657	0.715	1.946
29	120.49	74.52	0.365	0.068	0.422	0.444	1.183
30	102.51	51.96	0.254	0.057	0.330	0.307	0.817
31	**44.18**	**20.83**	**0.102**	**0.025**	**0.126**	**0.119**	**0.335**
32	101.43	28.29	0.138	0.057	0.340	0.160	0.456
33	63.98	43.43	0.213	0.036	0.209	0.256	0.687
34	125.47	41.99	0.205	0.072	0.386	0.228	0.664
35	74.13	44.27	0.217	0.042	0.266	0.263	0.708
36	83.91	35.61	0.174	0.047	0.260	0.205	0.557
37	189.02	56.31	0.276	0.108	0.644	0.314	0.891
38	229.99	95.15	0.466	0.130	0.724	0.544	1.502
39	216.05	105.48	0.517	0.124	0.737	0.614	1.685
40	174.14	88.41	0.433	0.098	0.605	0.519	1.393
41	234.21	93.52	0.458	0.132	0.739	0.535	1.475
42	175.76	101.87	0.499	0.101	0.610	0.600	1.628
43	181.21	92.83	0.455	0.106	0.578	0.525	1.461
44	83.53	60.75	0.298	0.047	0.273	0.361	0.964
45	70.89	32.64	0.160	0.039	0.220	0.194	0.518
46	599.51	114.87	0.563	0.341	1.945	0.602	1.830
47	**809.26**	**346.07**	**1.697**	**0.473**	**2.771**	**1.954**	**5.503**
48	251.87	257.03	1.260	0.141	0.847	1.547	4.022
49	109.90	104.33	0.511	0.062	0.347	0.626	1.654
50	805.07	139.03	0.682	0.456	2.720	0.731	2.211
51	381.14	321.61	1.577	0.217	1.304	1.925	5.088
52	507.87	183.63	0.900	0.284	1.601	1.059	2.898
53	404.35	217.09	1.064	0.226	1.309	1.298	3.478
54	268.61	169.99	0.833	0.149	0.815	1.020	2.713
55	430.62	155.95	0.765	0.246	1.422	0.893	2.504
56	461.12	219.89	1.078	0.267	1.501	1.258	3.487
57	388.85	186.27	0.913	0.222	1.402	1.089	2.954
58	279.89	175.56	0.861	0.160	0.890	1.020	2.745
59	162.28	111.89	0.548	0.094	0.565	0.661	1.784
60	115.02	64.82	0.317	0.065	0.384	0.378	1.015
61	265.93	69.46	0.340	0.149	0.892	0.389	1.100
62	784.88	200.67	0.984	0.446	2.650	1.106	3.183
63	175.60	84.872	0.416	0.104	0.619	0.474	1.326
Min.	**44.176**	**10.722**	**0.052**	**0.025**	**0.126**	**0.0530**	**0.1702**
Max.	**809.259**	**346.073**	**1.697**	**0.473**	**2.771**	**1.954**	**5.503**
Mean Value	**236.039**	**110.390**	**0.54153**	**0.012**	**0.791**	**0.641**	**1.747**

4. CONCLUSIONS

The results of gamma-ray measurements presented in this work give current information about natural and man-made radioactivity of basalt igneous rock samples collected from Aden governorate, South of Yemen. The results reveal the existence of U and Th natural seriesand ^{40}K, radionuclide's in a variety percentages depending on the location of samples within the mountain, approving the fact that for the lower regions large radionuclide's accumulation occurs which yield higher concentrations and vice versa. The average values of ^{226}Ra, ^{232}Thand ^{40}K activity, radium equivalent activity Ra_{eq}, gamma dose rate D, Indoor and outdoor annual effective dose rate E_{ied} and E_{oed}, External hazard index and internal hazard index H_{ex} and H_i were all found to be lower than the worldwide average values while the representative level index $I_{\gamma r}$ were all found to be higher than the worldwide average values.

REFERENCE

[1] N.K.Ahmed., J.Env.Radioact. 2005, 83, 91.

[2] Alias A. et al., the Malaysian Journal of Analytical Sciences, Vol. 12, No. 1, (2008).

[3] Mahur A. K. et al., Indian journal of Pure & Applied Physics, Vol. 48, July (2010), pp.486–492.

[4] Yang Ya-Xin. et al., Applied Radiation and Isotopes, 63 (2005) 255–259.

[5] Jasaitis D., and Girgždys A., Journal of Environmental Engineering and Landscape Management, Vol. XV, No. 1, (2007), pp. 313–317.

[6] Ward G.M., Johnson J.E., and Wilson D.W., Colorado Agricultural Experiment Station, Vol. 81, No.7, (1966).

[7] Harb, et al., Journal of Medical Physics, Vol. 37, No. 1, 2012.

[8] Adams, J.A.S. and Gasparini, Poalo, 1970. Gamma ray spectrometry of Rocks, Elsevier Publ. Co., New York, 295p.

[9] Hassan H. I., and Mheemeed A. Kh., Damascus University Journal for Basic Sciences Vol. 24, No. 2, (2008).

[10] Sujo L.C. et al., Journal of Environmental Radioactivity 77 (2004) 205–219.

[11] Diab H. M. et al., Journal of Nuclear and Radiation Physics, Vol. 3, No.1, (2008), pp. 53-62.

[12] Harb S. et al., Proceedings of the 3rd Environmental Physics Conference, 19–23 Feb. (2008), Aswan, Egypt.

[13] Tzortzis, M., Tsertos, H., Christofides, S., Christodoulides, G., 2002.Gamma-raymeasurements of naturally occurring radioactive samples from Cyprus characteristicgeological rocks. Preprint UCY–PHY–02/02(physics/0212099).

[14] Anas Maek El-Sherif (2005): Geology, Geochemistry and Radioactivity of the Basement rocks, Wadi El Ghozah area, North Eastern Desert, Egypt. PhD. Thesis, Fac. Sci., Ain Shams Univ., Cairo, Egypt, 218p.

[15] Khaled SA. Radioactivity Measurements of Some Environmental Samples Collected from Elba Protective Area, South Eastern Desert–Upper Egypt. PhD. Thesis, South Valley University 2006.

[16] Nagdya M. Ibrahiem. Radioactive Disequilibrium in the Different rock types in Wadi Wizr, the Eastern Desert of Egypt. Appl RadiatIsot 2003; 58:385-92.

[17] Ahmed NK, Abbady A, El-Arabi AM, Michel R, El-Kamel AH, AbbadyAG. Comparative Study of the Natural Radioactivity of Some Selected Rocks from Egypt and Germany. Indian J Pure Appl Phys 2006; 44:209-15.

[18] Bellia S, Brai M, Hauser S, Puccio P, Rizzo S. Natural Radioactivity in a Volcanic Island: Ustica, Southern Italy. Appl. Radiat Isot1997; 48:287-93

[19] Maphoto K. P., M. Sc. Thesis, University of the Western Cape, South Africa, (2004)