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Natural Radioactivity of Environmental Samples and their Impact on the Population at Assalamia-Alhomira Area in Yemen

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Abstract Measurements of the levels of natural background level of the radioactivity from ^{226}Ra and ^{232}Th (and their decay progeny), as well as the primordial radionuclide ^{40}K are the main objective of the current study. The present work investigated the radioactivity level of the rocks, soil and water samples at Assalamya-Alhomira area, Abyan district in Yemen. Thirty two rocks and soil samples and 3 groundwater samples from Assalamya-Alhomira area were analyzed by gamma-ray spectrometry using NaI(Tl) detector with specially designed shield. The concentration of three natural radionuclides namely ^{226}Ra, ^{232}Th, and ^{40}K has been determined. The results showed that these radionuclides were present in concentrations of (48.68±6.7, 28.8±3.3 and 1618±53 Bq kg^{-1}), (102.49±8, 149.8±8 and 2120±73 Bq kg^{-1}) and (769.5±39, 4125±124 Bq kg^{-1} and ^{40}K not detectable) for migmatitic biotite gneiss, psammitic and calc-silicate rocks, respectively. The highest activity concentration for ^{226}Ra and ^{232}Th is observed in calc-silicate rocks. From the microscopic study of the calc-silicate rocks we noted it consists of Calcite, Carbonate (Ca, Mg-CO3), diopside, magnetite and zircon minerals which accumulate in limited uranium and thorium. For clay and sandy soil the corresponding values were (41.46±5.6, 68.68±6 and 1224.7±31 Bq kg^{-1}) and (80.77±4.5, 211.5±14 and 1004.8±40 Bq kg^{-1}), respectively. Also radium equivalent activity, total dose rates and external hazard index of the (rocks/soil) samples in the area under consideration were calculated. The radioactivity concentration of ^{226}Ra and ^{232}Th for water samples ranged from 2.01±0.6 to 6.55±1.4 Bq l^{-1} and from 1.07±0.7 to 2.93±0.67 Bq l^{-1}, respectively, while ^{40}K activity was not detectable. The results showed that this area has a high background radiation due to the presence of Calc-silicate rocks which contain a high proportion of natural radioactive elements, and therefore represent a danger to the population lives in this area.

Keywords Natural radioactivity, Rock, Soil, Calc-silicate rocks, Radionuclides

1. Introduction

The radioactivity due to natural radionuclides in rocks, soil and water generate a significant component of the background radiation exposure to the population. The terrestrial component of the natural background is dependent on the compositions of the rocks, soil and water in which the natural radionuclides are contained[1]. Some areas are well known for their high background radiation like Rosetta in Egypt, the west cost of India and certain beaches in Brazil. Humans are exposed to natural terrestrial radiation that originates predominantly from upper 30 cm of the soil. Humans are also exposed by contamination of the food chain which occurs as a result of direct deposition of radionuclides on plant leaves, root uptake from contaminated soil or water and from direct ingestion of contaminated water. To assess these exposures radioactivity studies have been previously carried out in rock and soil samples in other part of the world, some similar to those by[2-12] and in water samples[13-20].

The present work is the first one aims to suppose the radiological assessment program of Yemen, with the ultimate aim to establish a base line map of radioactivity background levels in Yemen environment. Assalamya-Alhomira area located some 300 km south east of Sana'a, the population of this area is about 553 people, and this area is known as high incidence of cancer cases among people. A total of 23 cases cancer diagnosed between 1990-2010, including (12 liver cancers, 5 stomach cancers, 2 brain cancers, 2 colon cancers, 1 bowel cancer and 1cervical cancer).

This study deals with the natural radioactivity for rocks,

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soil and water in this area and assesses the radiological hazard resulting from them, using NaI(Tl) gamma-ray spectrometers. The absorbed dose rate, radium equivalent activities, external hazard index were evaluated and compared to the limits proposed by united nation scientific committee on the effect of atomic radiation[21].

2. Experimental

2.1. Geological Outline

The study Assalamya-Alhomira area (~20 km^2) is located some (300 km) southeast of Sana'a and located in Lat. 13°47'47"N and long 45°56'22"E. Assalamya-Alhomira area consist of Precambrian basement includes gneissic granite, pegmatite and biotitic gneiss[22]. Precambrian rocks are invaded by numerous calc-silicate bodies. Basement rocks are some of the oldest structures dating back to about 3 billion years. Magmata rocks, gneiss and schist rocks represent such structures. These structures appear as belts extending for tens of kilometers as ancient areas separating the small sheets which joined together and formed the Arab-African Shield[23].

2.2. Sampling and Sample Preparation

2.2.1. Rocks and Soil Samples

A total of 23 rocks and 9 surface soil samples have been collected randomly from the studied area. Rock sample was crushed to small pieces and grinded to be powder. Soil samples were collected with the only constraint that no sampling site should be taken close to a field boundary, a road, a tree or other obstruction. Surface soils were then taken from different places randomly within cleared area from the ground surface up to 2 cm and mixed together thoroughly in order to obtain a representative sample of that area. Each sample (rock/soil) was dried in an oven at 105°C and sieved through a 18 mesh which is the optimum size enriched in heavy mineral[24]. The samples were packed in plastic containers dimensions of 75 mm in diameter and 90 mm height. The samples were weighed and stored for a minimum period of one month to allow daughter products to come into radioactive equilibrium with their parents ^{226}Ra and ^{232}Th and then were counted for 12-24 hour depending on the concentration of the radionuclides.

2.2.2. Water Samples

Because no running water in this area 3 groundwater samples were collected from the study area that used as drinking water. Measuring pH values as well as conductivity for water samples were measured in the laboratory. Standard polyethylene Marinelli beakers (1 liter) were used as a sampling and measuring container. Before use, the containers were washed with dilute hydrochloric acid and rinsed with distilled water. Each beaker was filled up to brim and a tight cap was pressed on so that the air was completely removed from it. The collected water samples were left for an overnight period in polyethylene containers to allow setting of any suspended solid materials and for each samples a clear supernatant was separated decantation. The clear solution was acidified by adding 0.5 ml of conc. HNO_3 per liter, to prevent any loss of radium isotopes around the container walls, and to avoid growth of micro organisms[25]. The water samples were then homogenized well by shaking. The final acidity of water samples reaches pH-2. The samples were stored for over 30 days to reach secular equilibrium before radiometric analysis.

2.3. Experimental Setup

Each sample was measured with a gamma-ray spectrometer consisting of a NaI(Tl) setup and multichannel analyzer 8192 channel, with the following specifications: resolution (FWHM) at 1.33 MeV ^{60}Co is 60 keV – relative efficiency at 1.33 MeV ^{60}Co is 7.5 %. The detector is shielded in a chamber of two layers starting with stainless steel (10 mm thick) and lead (30 mm thick). This shield serves to reduce different background radioactivity.

To minimize the effect of the scattered radiation from the shield, the detector is located in the center of the chamber. Then the sample was placed over the detector for at least 10 h. The spectra were either evaluated with the computer software program Maestro (EG&G ORTEC), or manually with the use of a spread sheet (Microsoft Excel) to calculate the natural radioactivity. ^{226}Ra activity of the samples was determined via its daughters (^{214}Pb and ^{214}Bi) through the intensity of the 295.22, 351.93 keV, for ^{214}Pb Gamma-lines and 609.31, 1120, 1764.49 keV, for ^{214}Bi Gamma-lines. ^{232}Th activity of the sample was determined from the daughters (^{228}Ac), (^{212}Pb) and (^{208}Ti) through the intensity of 209.25, 338.32, 911.2 keV Gamma-lines for (^{228}Ac), (^{212}Pb) emissions at 238.63 keV and (^{208}Ti) emissions at 583.19, 2614 keV Gamma-lines. ^{40}K activity determined from the 1460.7 keV emissions Gamma-lines.

2.4. Calculation of the Radiological Effects

The most widely used radiation hazard index Ra_{eq} is called the radium equivalent activity. The radium equivalent activity is a weighted sum of activities of the ^{226}Ra, ^{232}Th and ^{40}K radionuclides based on the assumption that 370 Bq kg^{-1} of ^{226}Ra, 259 Bq kg^{-1} of ^{232}Th and 4810 Bq kg^{-1} of ^{40}K produce the same gamma ray dose rate[26]. Radium equivalent activity can be calculated from the following relation suggested by Beretka and Mathew[27].

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

Where A_{Th} is the activity concentration of ^{232}Th in Bq kg^{-1}, A_{Ra} is the activity concentration of ^{226}Ra in Bq kg^{-1}, A_K is the activity concentration of ^{40}K in Bq kg^{-1}.

External hazard index due to the emitted gamma-rays of the samples are calculated and examined according to the following criterion:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1, \quad (2)$$

Where; A_{Ra}, A_{Th}, A_K are the activity concentrations of ^{226}Ra,

^{232}Th and ^{40}K, respectively. The calculated average external hazard index was found to be less than unity.

The total air absorbed dose rate (nGy.h^{-1}) due to the mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K (Bq kg^{-1}) can be calculated using the formula as in[28] and[29].

$$D = 0.462A_{Ra} + 0.604A_{Th} + 0.042A_K \quad (3)$$

Where: A_{Ra}, A_{Th} and A_K are the mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively, in (Bq kg^{-1}). Reference[9] derived this equation for calculating the absorbed dose rate in air at a height of 1.0 m above the ground from measured radionuclides concentrations in environmental materials.

3. Results and Discussion

3.1. Natural Radioactivity in Rocks and Soil Samples

Table 1 shows the chemical results of the rock analyses by XRF, The major oxides in rocks and soil samples are Cl, CaO, BaO, Fe_2O_3, SO_3, SrO and K_2O. The high values of U (^{226}Ra) and ^{232}Th measured in rocks can be attributed to the high positive correlation between these elements and CaO and Fe_2O_3, and negative correlation with Cl. Also the high values of ^{232}Th measured in calc-silicate rocks can be attributed to the high positive correlation between thorium and BaO, SrO and SO_3 which explains the higher values of thorium in calc-silicate rocks.

Table 2 shows a summary of measurement for the activity concentration (Bq kg^{-1}) of the natural radioactivity levels in rocks and soil due to ^{226}Ra, ^{232}Th and ^{40}K. The table also lists the type of rock. The distribution of ^{226}Ra, ^{232}Th and ^{40}K activity concentrations in all samples are given in Fig.2.

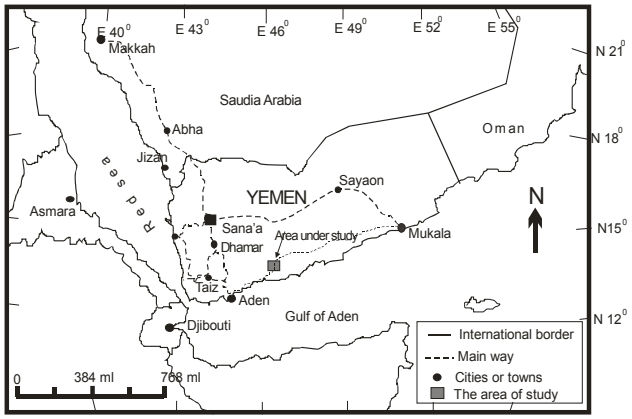
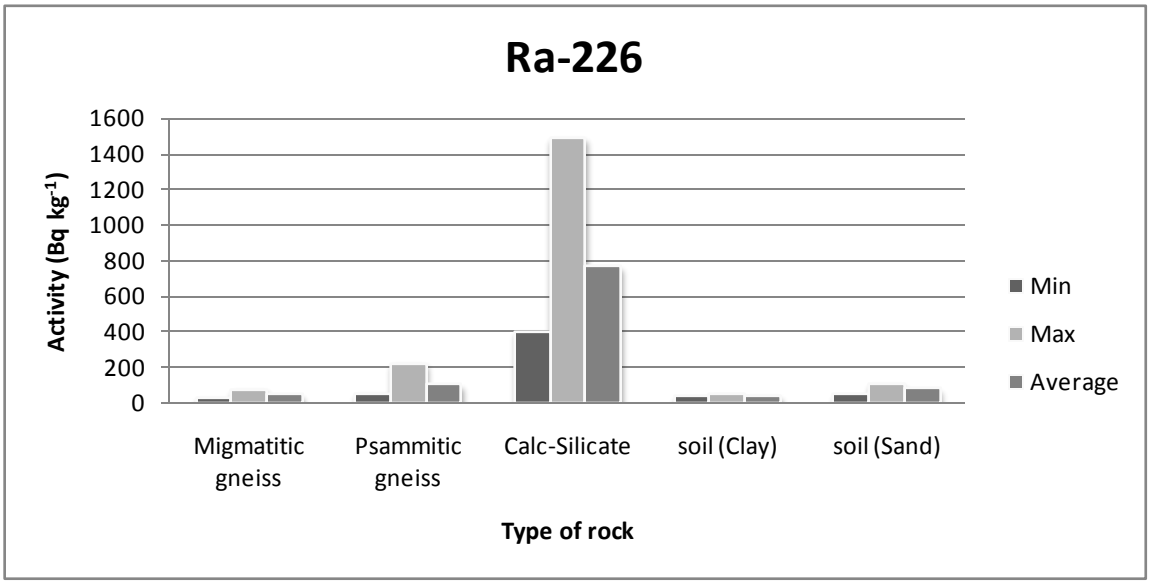


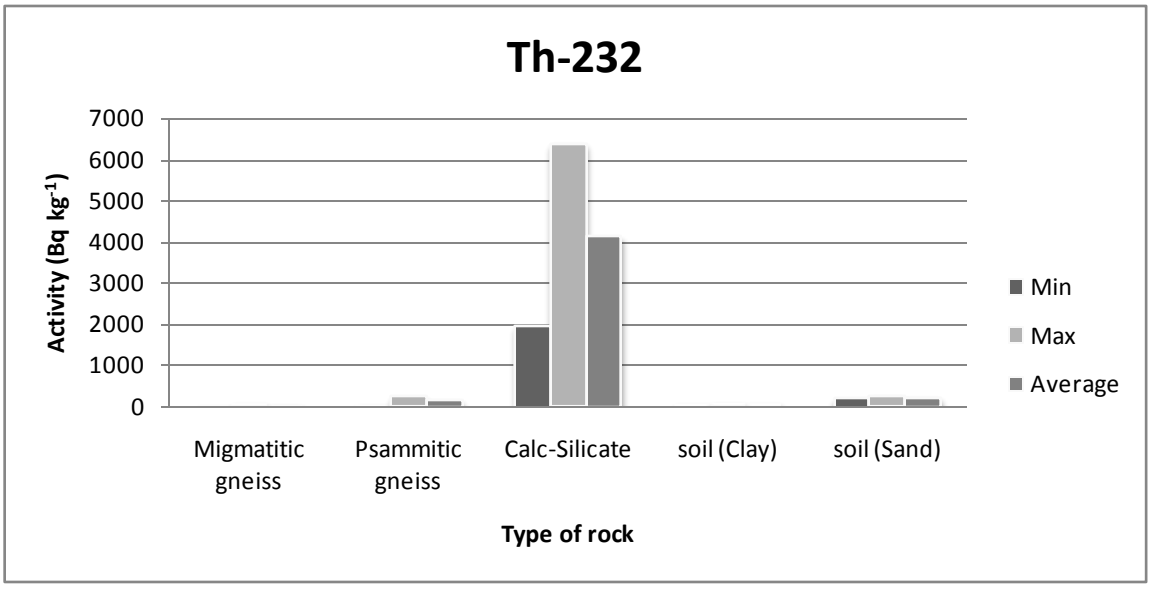
Figure 1. A map showing the study area

Table 1. Chemical results of the analyzed samples. Concentrations are expressed in wt%

Type of rock	Calc-silicate					Biotite gneiss		Psammitic	Soil	
									clay	sand
S. No.	14	15	19	21	22	3	4	8	4	7
CaO	19.97	15.09	26.48	18.67	13.8	*	0.6	*	*	12.4
BaO	16.8	18.99	7.5	15.5	20.47	*	*	*	*	*
SrO	1.11	1.02	1.05	1.09	1.12	*	*	*	*	*
SO_3	3.32	3.57	1.4	2.9	3.97	*	*	*	*	*
Fe_2O_3	4.67	5.38	9.33	5.12	5.07	2.02	1.49	0.96	5.4	11.58
SiO_2	*	*	1.5	*	*	14.75	14.75	*	*	8.3
K_2O	*	*	*	*	*	4.8	6.77	1.49	*	2
Al_2O_3	*	*	*	*	*	*	*	*	*	1.44
TiO_2	*	*	*	*	*	*	*	*	*	1.75
Cl	53.4	55.9	51.37	56.68	55.5	78.38	76.3	97.54	94.54	62.53
Total	99.27	99.95	98.63	99.96	99.93	99.95	99.91	99.99	99.94	100

*Not detectable





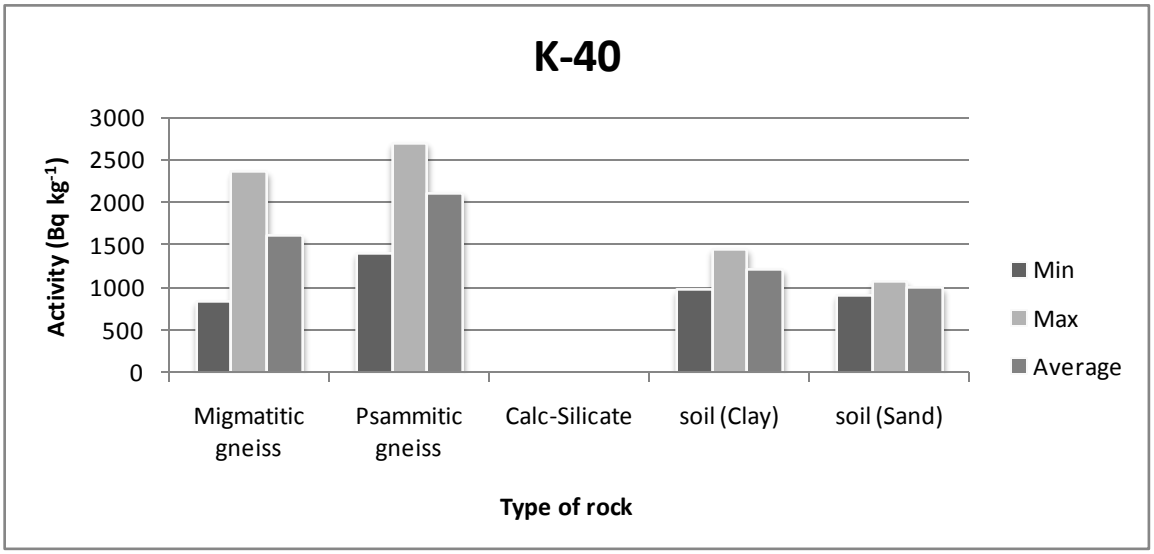


Figure 2. Distribution of ^{226}Ra, ^{232}Th and ^{40}K in Rocks and soil from Assalamya-Alhomira area in Yemen

Table 2. Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K (Bq kg^{-1}) and radiological hazard indices of rocks and soil samples from Assalamya-Alhomira area in Yemen

Sample No.	Type of Rocks	Activity Bq kg-1			Dose rate (nGy h-1)	Raeq (Bq kg-1)	Hex
		226Ra	232Th	40K			
1	Miga gneiss	40.2±6	20.3±2.5	2370.4±77	131.8	251.7	0.7
2	Mig. gneiss	59.6±6.6	68.1±4	1639.7±54	137.2	283.2	0.8
3	Mig. gneiss	78.4±9	22.1±3.8	1505±49	113.1	225.9	0.6
4	Mig. gneiss	31.9±6.3	22±4	1727±56	101.4	196.3	0.5
5	Mig. gneiss	33.5±5.5	11.3±2.4	848±27.6	58.2	115.0	0.3
6	Mean	48.68±6.7	28.8±3.3	1618±52.7	108.34	214.42	0.58
6	Psab. Gneiss	224.7±11	31.7±3	2640±86	234.0	473.3	1.3
7	Psa. gneiss	70.6±7	165.3±6.3	2532±82	237.2	501.9	1.4
8	Psa. gneiss	111±8	199.3±7.5	2219±72	262.0	566.9	1.5
9	Psa. gneiss	71.1±9	241.9±9.3	1415±49	234.2	525.9	1.4
10	Psa. gneiss	93.8±8	157.2±10	2705±91	250.4	526.7	1.4
11	Psa. gneiss	110±8	151±11	2575±91	248.7	524.3	1.4
12	Psa. gneiss	83.3±10	130±9	1528±55	179.3	386.8	1.0
13	Psa. gneiss	55.4±4	122±9	1352±54	154.3	333.7	0.9
	Mean	102.49±8	149.8±8	2120.8±73	225.01	479.94	1.29
14	Calc-silicate	1011±39	4953±142	*	3350.2	8093.8	21.9
15	Calc-silicate	1134.8±45	5492±166	*	3720.9	8988.1	24.3
16	Calc-silicate	433.7±23	1941±65	*	1330.0	3209.3	8.7
17	Calc-silicate	403.6±27	2215.9±75	*	1476.7	3572.3	9.6
18	Calc-silicate	687.4±45	4209±139	*	2768.8	6706.3	18.1
19	Calc-silicate	1490.6±59	3083±103	*	2477.3	5899.3	15.9
20	Calc-silicate	538.5±21	4337±122	*	2775.7	6740.4	18.2
21	Calc-silicate	887.7±53	6381±186	*	4127.3	10012.5	27.0
22	Calc-silicate	633±42	5062±145	*	3241.8	7871.7	21.3
23	Calc-silicate	475±35	3579±103	*	2304.5	5593.0	15.1
	Mean	769.5±39	4125±124.6	*	2757.32	6668.67	18.01
1	Soil (Clay)	38±6	57.9±5	1243.7±32	121.9	258.7	0.7
2	Soil (Clay)	41±4	60.2±4	1218±44	123.0	256.2	0.7
3	Soil (Clay)	41.8±6	70±6	983±28	104.4	216.6	0.6
4	Soil (Clay)	51.14±7	79.7±7	1215±30	106.0	220.9	0.6
5	Soil (Clay)	35.4±5	75.6±8	1464±40	102.0	217.6	0.6
	Mean	41.46±5.6	68.68±6	1224.7±32	111.46	234	0.64
6	Soil (Sand)	97±10	221±13	1009±33	216.4	490.7	1.3
7	Soil (Sand)	110.3±11	247.9±15	1073±36	240.9	547.4	1.5
8	Soil (Sand)	50.5±6	190.5±14	1016±25	177.7	401.1	1.1
9	Soil (Sand)	65.6±7	187.5±13	921±27	178.8	404.6	1.1
	Mean	80.77±10	211.5±14	1004.8±40	203.45	460.95	1.25

*Not detactable, a migmatitic biotite and b Psammitic

From table 2 it can be seen the highest activity concentration for ^{226}Ra and ^{232}Th is observed in calc-silicate rocks (769.5±39 and 4125±124.6 Bq kg^{-1}), respectively, while the lowest activity concentrations observed in migmatitic biotite gneiss (48.68±6.7 and 28.8±3.3 Bq kg^{-1}), respectively. From the microscopic study of the calc-silicate rocks we noted it consists of Calcite, Carbonate (Ca, Mg-CO3), diopside and magnetite minerals which accumulate in limited uranium and thorium. Also microscopic study reveals that calc-silicate rocks contains high amount of zircon mineral (Fig. 3) (zircon often contain traces radioactive elements in its structure, like uranium, thorium and yttrium, because Th and U may substitute zirconium in the zircon crystal lattice) which reflect the high radioactivity of these rocks samples. There are few studies on this type of rock in the literature, Similarly, as in[2] also reported the highest radium equivalent (70124.5 Bq kg^{-1}) in calc-silicate rocks from Pedra-Pernambuco in Brazil. Calc-silicate rocks contains high amount of iron oxides (Fe_2O_3) and Calcium oxide (CaO) which have the ability of capturing uranium and thorium from circulating solutions. Also good positive correlation noted between these elemental oxides with the concentration of ^{232}Th and ^{226}Ra in many literature studies[3-4].

The results in table 2 show that psammitic rocks are rich in ^{40}K. The average concentration of ^{40}K was measured as 2120.8±73 Bq kg^{-1}. These values are approximately 4 times higher than the average concentration value (412 Bq kg^{-1}) as in[21]. The high ^{40}K concentration of the psammitic rocks is consistent with their high potassium feldspar mineral contents (plagioclase, microcline and quartz).

Also from the table we noted the activity concentrations values for ^{226}Ra, ^{232}Th and ^{40}K in sandy soil are higher than the activity concentrations for clay soil these because the

sandy soil is contain more elemental oxide such as CaO, Fe_2O_3, SiO_2, K_2O, Al_2O_3 and TiO_2 rather than clay soil. The highest activity concentrations for ^{226}Ra, ^{232}Th and ^{40}K in soil samples can be explained in relation to geological structure of this area under study where this area is located near the calc-silicate and psammitic rocks. Similarly, as in[5] also reported the high Activity concentrations for ^{226}Ra (299, 1001 and 4043 Bq kg^{-1}) in Anchieta, Meaipe and Guarapari sits respectively, in Brazilian beach sands. The activity concentrations for natural radionuclide in soil in the present study are higher than in literature[6-8]. The average activity concentrations for ^{226}Ra, ^{232}Th and ^{40}K in the present study are higher than worldwide average for these radionuclides in the soils (32, 45 and 412 Bq kg^{-1}) as in[2] for ^{226}Ra, ^{232}Th and ^{40}K, respectively.

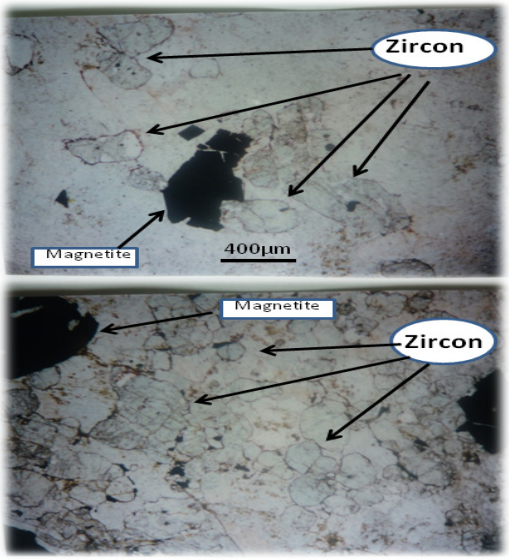


Figure 3. Zircon and magnetite minerals encountered within calc-silicate rocks in Assalamya-Alhomira area

3.1.1. Radiation Hazard Indices

The absorbed dose rates in air 1.0 m above ground were calculated and given in table 1. The average absorbed dose rates for migmatitic biotite gneiss, psammitic and calc-silicate rocks are 108.34, 225.01 and 2757.32 nG h^{-1}, respectively. According to the recent UNSCEAR reports the corresponding worldwide average values is 58 nG h^{-1}. This reveals that the mean absorbed dose rates in air outdoors from these rocks are almost two, four and forty eight times higher than that of worldwide average value, respectively (Table 2).

For soil the average absorbed dose rates in air are 111.46 and 203.45 nG h^{-1} for clay and sandy soil respectively. This means that the mean absorbed dose rates in air outdoors from soil approximately two and three past half times higher than that of worldwide average value.

The calculated Ra-equivalent activities of the migmatitic biotite gneiss rocks are below the recommended value 370 Bq kg^{-1} as in[27] (Table 2), while the corresponding value for psammitic rocks is higher than recommended value (Table 2). For calc-silicate rocks the average Ra-equivalent activities is about eighteen higher than recommended value. For clay soil the corresponding value is below the recommended value but for sandy soil the Ra-equivalent value is higher than the recommended value (Table 2).

The external hazard index (Hex) can be calculated from the equation 2 as in[27]. The results of H_{ex} based on the criterion formula (Eq. (2)) are given in Table 2. The average values are 0.58, 1.29 and 18 for migmatitic biotite gneiss, psammitic and calc-silicate rocks, respectively. The recommended value is less than unity as in[21]. For soil the corresponding values of H_{ex} are 0.64 and 1.25 for clay and sandy soil, respectively.

When the results of this study for psammitic rocks are compared to the results of some of the previous studies ([3],[9],[10]) for granite rocks, it is clear that the results are less than those from Egypt, while similar to ([6],[11]) from Yemen and India. For calc-silicate rocks the results of this study is less than[2] from Brazil for the same type of rocks, while it is effectively superior to the values found in the literature for granite rocks. The values that were found for the sandy soil in the present study were superior to the global average as in[21], as well as to other studies ([6-8],[12]).

3.2. Natural Radioactivity in the Groundwater

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the groundwater that it used as drinking water in the study area were shown in table 3. The pH and conductivity can be also seen from table 3. As seen, all of the water samples have natural pH (8.38, 9.04 and 8.96) for sample 1, 2 and 3 respectively. The high alkalinity of water samples explain the high alkalinity of rocks in this area and reflect the high natural radioactivity in water samples.

Table 3. Associated characteristics and activity concentrations (Bq l^{-1}) of natural radionuclides in water samples

Sample No.	latitude	longitude	pH	Conduct µscm^{-1}	Activity concentrations (Bq l^{-1})		
					^{226}Ra	^{232}Th	^{40}K
1	13°47'41"N	45°55'42"E	8.38	6940	6.55±1.4	2.93 ±0.67	ND
2	13°47'54.4"N	45°56'5.4"E	9.04	5700	3.58±1.3	1.43 ±0.8	ND
3	13°46'41"N	45°54'41"E	8.96	1050	2.01±0.6	1.07 ±0.7	ND

ND not detectable.

The concentrations of ^{226}Ra and ^{232}Th varied from 2.01 to 6.55 Bq l^{-1} and from 1.07 to 2.93 Bq l^{-1}, respectively, while ^{40}K was not detectable in these samples. Reference values for ^{226}Ra and ^{232}Th radioactivity concentrations in drinking water are 0.5 and 0.05 mBq l^{-1}, respectively as in[2]. These guidelines ensure an exposure lower than 0.1 mSv y^{-1} assuming a water consumption rate of 2 l per day. As seen from the table 3, the concentration of ^{226}Ra and ^{232}Th are

much higher than reference value.

The results obtained in this study are much higher than those obtained in other countries like Syria, Turkey, Sudan and Brazil[13-16], but are lower than those found in Niger delta in Nigeria[17].

The highest activity concentration for ^{226}Ra and ^{232}Th in waters samples can be good indicator for the high concentrations of radionuclides in the aquifer rocks[18-19]. Assalamya-Alhomira area contains rocks such as psammitic and calc-silicate which enrich in quarts and feldspar and radioelement's ^{226}Ra and ^{232}Th. Also concentration of ^{226}Ra in water samples are higher than that of ^{232}Th and this reflect the fact that radium is more soluble in groundwater than its thorium and uranium precursors, and its solubility is enhanced by: 1) the common-ion effect (when dissolved solids are high), 2) an oxygen-poor environment, and 3) the fragmentation of uranium-bearing minerals[20].

4. Conclusions

In the present study activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K for rocks, soil and water are evaluated. The average activity concentrations for migmatitic biotite gneiss and clay soil were inferior to the maximum recommended values (32, 45 and 412 Bq kg^{-1}) as in[21]. On the other hand, the psammitic rocks presented ^{226}Ra, ^{232}Th and ^{40}K average values are 102.49, 149.8 and 2120 Bq kg^{-1}, which is about three times higher than the recommended limit. For calc-silicate rocks the corresponding values for ^{226}Ra and ^{232}Th are 769.5 and 4125 Bq kg^{-1}, which are approximately 23 times higher the recommended values for ^{226}Ra and approximately 85 times superior to the maximum recommended limit for ^{232}Th. For sandy soil the activity concentration for ^{226}Ra, ^{232}Th and ^{40}K are 80.77, 211.5 and 1004.8 Bq kg^{-1}, which is about much higher than the recommended values. The results obtained for rocks and soil from this area are much higher than recommended limits and provide excessive exposure for inhabitants and cannot be used as construction materials with posing significant radiological threat to the population.

Having those values to estimation the absorbed dose rate, radium equivalent and radiation hazard index, we can recommended in cases of psammitic, calc-silicate rocks and sandy soil should not be used as building materials, and considering the safety of the human population of studied area, it is suggested that the area should be avoided or seldom utilized.

The groundwater data obtained in present study show the activity concentrations of ^{226}Ra and ^{232}Th ranged from 2.01 to 6.55 Bq l^{-1} and from 1.07 to 2.93 Bq l^{-1}, respectively, While ^{40}K was not detectable in these samples. The high activity concentrations for ^{226}Ra and ^{232}Th measured in water samples explain the relationship between the groundwater and calc-silicate rocks in the region, for this reason we suggests the investigated groundwater are not acceptable as drinking water.

Therefore, the present study has pointed out the area under study need further studies in order to better understand the origin and distribution of naturally occurring radionuclides.

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