Measurements of Natural Radionuclides in Soil samples from Tourbh Governorate, Saudi Arabia

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Abstract The level of natural radioactivity in forty nine soil samples collected from Tourbh governorate, Saudi Arabia were measured using gamma ray spectrometer. Analyses of soil samples have been performed to determine the radioactive concentrations of ^{226}Ra, ^{232}Th and ^{40}K. The results show that these radionuclides concentrations present in Bq/kg and ranged from 1.95±0.08 to 13.07±0.5, 1.33±0.11 to 10.04±0.61and 39.92±3.43 to 193.71±16.66 for ^{226}Ra, ^{232}Th and ^{40}K respectively. To assess the radiation hazard, the radium equivalent activity (Ra_{eq}), the representative level index, I_{gr}, and absorbed dose in air for all samples were calculated. The data were discussed and compared with the published data in different countries.

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1. Introduction

Natural radioactive materials are the most important source of radiation exposure to humans. Although these materials contain low-level radioactivity, the accumulated dose can be high. Measurements of the radiation exposure and radiation levels have been developed recently (UNSCEAR 1988, 1993). It is well known that, natural radioactivity is presented in rocks, soil, sediment, water and fish (Parker 1967). Rocks and soil contain small quantities of the radioactive elements of U and Th with their daughter products. The concentration of these elements varies considerably depending on the soil formation (NCRP, 1975).

Soils are complex mixtures of minerals, organic compounds, and living organisms that interact continuously in response to natural and imposed biological, chemical, and physical forces. A soil not only consists of organic and inorganic compounds but also radionuclides. The naturally occurring radionuclides present in soil include ^{40}K, ^{226}Ra and ^{232}Th (Khan et al., 1998). Gamma radiation emitted from those naturally occurring radioisotopes, called terrestrial background radiation, represents the main source of irradiation of the human body and contributes to the total absorbed dose via ingestion, inhalation and external irradiation (Steinhausler 1992). Calculations by Beck (1972) suggested that 50 - 80 % of the total gamma flux at the earth's surface arises from ^{40}K, ^{238}U and ^{232}Th series in top soil.

This study determined the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples from Tourbh governorate, in Saudi Arabia, which locate about 130 km from El- Taef town and 120 km from El-Baha town. *In order to understand the occurrence and distribution of natural radionuclides of soil samples in area under investigation and evaluate potential health hazards;* the radium equivalent activity (Ra_{eq}), the representative level index, I_{gr}, and absorbed dose in air for all soil samples were *estimated to assess the contribution of this radionuclide to public exposure.*

2. Materials and Methods

2.1. Soil samples collection and preparation

A total of 49 samples were collected from the Tourbh governorate which located on21° 12′ 41.09″ N, 41° 38′ 14.09″ E. In order to obtain a representative sample, the soil collected at each site were thoroughly mixed together, sieved to remove stones and pebbles, and crushed to pass through a 2mm mesh sieve to homogenize it, then, the soil samples of were air-dried for several days, placed in an oven at 100°C and weighed. Finally, a split of each prepared sample was packed in a bottle 250 ml polypropylene bottle; which was sealed and left for at least 4 weeks before counting by gamma spectrometry in order to ensure that radioactive equilibrium was reached between ^{226}Ra, ^{222}Rn, and ^{222}Rn progeny (Quindos 1994; El-Taher, and Madkour, 2010).

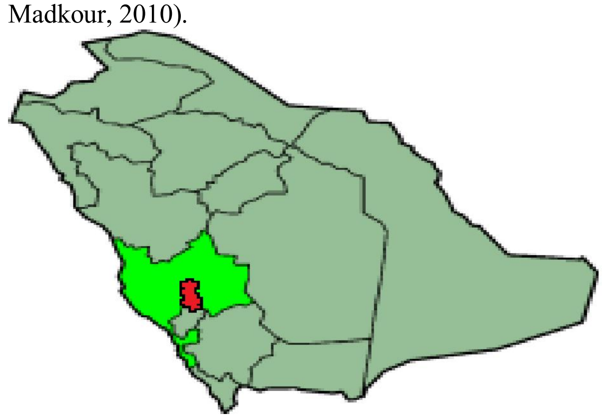


Figure (1) Saudi Arabia map include Study area (red color).

2.2. Experimental set up

Measurements had been carried out using low-level gamma ray spectrometer. It consists of ″3x3″ NaI (Tl), S-1212-I model, with a 1024 microcomputer multichannel analyzer, 5510 Ortec Norland. The 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 V dc. The detector was housed inside a massive cylindrical lead shield with quarter 50 cm to reduce the background radiation. The system was calibrated for energy using standard point sources (^{60}Co, ^{137}Cs), and calibrated for efficiency.

2.3. Calculations

2.3.1. Activity concentrations

Every sample was placed in face to face geometry over the detector for around 12 hour. Prior to sampling counting, background were normally taken every week under the same condition of sample measurement. The analysis of ^{226}Ra and ^{232}Th depends upon the peaks of the decay products in equilibrium with their parent nuclides. The content of ^{226}Ra was measured using gamma-lines of ^{214}Pb and 352 (37%) keV) and ^{214}Bi (609.32 keV (44.6%), 1120 (15%) and 1765 (16%) keV). The concentration of ^{232}Th was determined using gamma-lines of ^{228}Ac (911.16 keV (26.6%)), and ^{212}Pb (238(43%). ^{40}K was determined by measuring its single peak at 1460.8 keV (10.67%) (El-Taher, 2010).The radioactivity concentration in the environmental samples was calculated from the following equation (1):

$$A= ((N/T)-(n/t))/ \eta MP \qquad (1)$$

Where A is the activity concentration Bq/kg, N is the number of counts in a given peak area, T the sample counting lifetime, n is the number of counts in background peaks, t is the back ground counting time, P the number of gammas per disintegration of this nuclide (emission probability), M is weight in kg of the measured sample, η is the detection efficiency at measured energy.

2.3.2. Assessment of radiological hazards

2.3.2. 1. Estimation of absorbed dose rate

The conversion factors were used to compute the absorbed dose rate in air per unit of specific activity concentration in soil for ^{40}K, ^{226}Ra and ^{232}Th as in equation (2).

$$D(nGy/h)=0.0417C_K+0.462\ C_{Ra} + 0.604\ C_{Th} \qquad (2)$$

Where C_{Ra}, C_{Th} and C_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg respectively.

2.3.2. 2. Radium equivalent activity

Radium equivalent activity is an index that has been introduced to represent the specific activities of ^{226}Ra, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them. This first index can be calculated according to the following equation (3):

$$Ra_{eq} = C_{Ra} + (10/7)\ C_{Th} + (10/130)\ C_K \qquad (3)$$

Where C_{Ra}, C_{Th} and C_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively (Beretka and Mathew 1985, Abbady 2004).

2.3.2. 3. Representative level index

Another radiation hazard index called the representative level index ($I_{\gamma r}$) is defined as follows in equation (4):

$$I_r = (1/150)\ C_{Ra} + (1/100)\ C_{Th} + (1/1500)\ C_K \qquad (4)$$

Where C_{Ra}, C_{Th} and C_K are specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively (NEA 1979).

2.3.2. 4. Annual effective dose rates

To estimate the annual effective dose rates, the conversion coefficient from absorbed dose in air to effective dose (0.7 Sv/Gy) and outdoor occupancy factor (0.2) proposed by UNSCEAR were used (UNSCEAR 2000). The effective dose rate in unit of mSv/a was calculated by the following the following equation (5):

$$D_{eff}\ (mSv/a) = \text{Dose rate } (nGy/h) \times 8760\ h \times 0.2 \times 0.7\ Sv/Gy \times 10^{-6} \qquad (5)$$

3. Results and Discussions

The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the measured soil samples expressed in Bq/kg were ranged between 1.95±0.08 to 13.07±0.5, 1.33±0.11 to 10.04±0.61 and 39.92±3.43 to 193.71±16.66 with activity weighted means 4.35±0.028, 3.3±0.033 and 71.74±7.21 respectively, table (1). The ^{40}K activity is higher than ^{232}Th and ^{226}Ra in all the samples. In order to test the correlations between ^{226}Ra and ^{232}Th, ^{226}Ra and ^{40}K and ^{232}Th and ^{40}K the obtained concentrations of naturally occurring radionuclides were plotted in the histogram figures (2). It is noted that a good correlation between ^{226}Ra and ^{232}Th was observed with a correlation coefficient of 0.7, whereas a poor correlations between ^{226}Ra with ^{40}K and ^{232}Th with ^{40}K were observed, with a correlation coefficients of 0.019 and -0.013 respectively. According to the recommended reference level of 30, 25 and 370 Bq/kg for ^{226}Ra, ^{232}Th and ^{40}K respectively, for the World average concentrations published by UNSCEAR, it is noted that the obtained results in most samples are lower than the recommended reference level (UNSCEAR 1988).

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil samples from the studied areas was compared with those from similar investigations in other countries and summary results were given in table (2).The comparison shows that the values of soils under consideration are extremely low in accordance with others. The radium equivalent activity of each sample was estimated using the equation (4).The mean value of radium equivalent activities of all soil samples is 20.16Bq/kg. The mean value obtained for radium equivalent activity is too low in comparison with the limited value 370Bq/kg reported by Beretka and Mathew (1985).

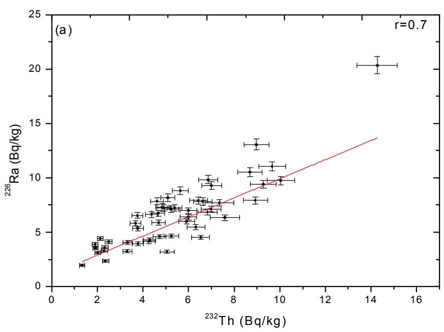
The representative level index $I_{\gamma r}$ is less than unity for all samples under test which is in good agreement with other studies (Taha, 2006; UNSCEAR 2000). At last, the calculated effective doses are small values which can be attributed to the content of radionuclides which is very low for all samples. The average annual dose from natural sources is 2.4 mSv which is a reference level representing the range 1~10 mSv/a and in extreme cases to 1 Sv or more (UNSCEAR 2000).

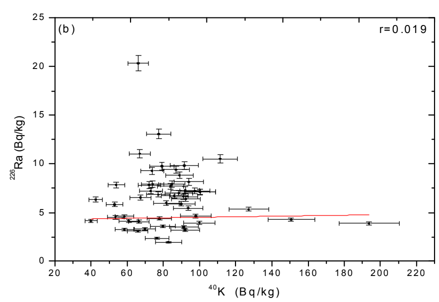
Table (1) Activity concentration in Bq/kg of ^{226}Ra, ^{232}Th and ^{40}K in soil samples with the external gamma dose rate (D_{eff}), Ra equivalent activity (R_{aeq}), representative level index (I_{γ}), and effective dose rate (mSv/a)

Sample code	Location	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	D (nGy/h)	Ra_{eq} (Bq/kg)	I_r (Bq/kg)	D_{eff} (mSv/a)
1	KaryAlqapha street	7.12±0.28	5.24±0.33	100.26±8.62	10.63	22.31	0.17	0.013
2	Kary	7.14±0.28	6.98±0.44	100.31±8.63	11.7	24.83	0.18	0.014
3	East Kary	6.75±0.26	4.67±0.29	86.16±7.41	9.53	20.05	0.15	0.012
4	ElsardyKary	4.15±0.17	4.26±0.26	39.92±3.43	6.15	13.31	0.1	0.007
5	ElwadaKary	9.83±0.38	6.85±0.43	91.61±7.88	12.5	26.67	0.2	0.015
6	North Kary	7.92±0.31	6.43±0.39	84.64±7.28	11.07	23.61	0.17	0.013
7	Alqapha street	4.39±0.18	2.12±0.13	77.71±6.68	6.55	13.4	0.1	0.008
8	Alqapha street A	3.94±0.15	3.79±0.23	99.81±8.59	8.27	17.03	0.13	0.01
9	Alqapha street B	7.22±0.28	4.91±0.3	97.35±8.37	10.36	21.72	0.16	0.013
10	South Kary	6.63±0.26	4.38±0.27	91.09±7.84	9.51	19.9	0.15	0.012
11	Ranya- Alqapha St. A	1.95±0.08	1.33±0.11	82.81±7.12	5.16	10.22	0.08	0.006
12	Ranya- Alqapha St. B	6.34±0.25	7.59±0.65	42.55±3.66	9.29	20.45	0.15	0.011
13	Ranya- Alqapha St. C	2.35±0.1	2.35±0.14	76.48±6.58	5.69	11.59	0.09	0.007
14	Ranya Street	11.04±0.43	9.66±0.59	66.89±5.75	13.72	29.98	0.21	0.017
15	MfrakKary	3.52±0.14	1.92±0.12	91.32±7.86	6.59	13.28	0.1	0.008
16	Alqapha street C	4.29±0.17	4.29±0.26	150.65±12.96	10.86	22.01	0.17	0.013
17	Alsnaya A	4.06±0.16	3.32±0.2	66.42±5.71	6.65	13.92	0.1	0.008
18	Alsnaya B	3.27±0.13	3.31±0.2	58.56±5.04	5.95	12.5	0.09	0.007
19	Alsnaya C	7.72±0.3	7.35±0.63	84.02±7.23	11.51	24.69	0.18	0.014
20	Alsnaya D	6.54±0.26	3.76±0.23	67.3±5.79	8.1	17.09	0.13	0.01
21	East Alhayrya A	8.16±0.35	5.09±0.31	94.07±8.09	10.77	22.67	0.17	0.013
22	East Alhayrya B	5.98±0.24	5.92±0.36	81.53±7.01	9.74	20.71	0.15	0.012
23	East Alhayrya C	10.53±0.41	8.7±0.53	111.43±9.59	14.76	31.52	0.23	0.018
24	East Alhayrya D	6.39±0.25	5.99±0.37	92.39±7.95	10.43	22.06	0.16	0.013
25	Middle Alhayrya	7.92±0.31	8.93±0.54	74±6.37	12.14	26.37	0.19	0.015
26	Alhayra E	5.9±0.23	4.68±0.29	89.76±7.72	9.3	19.49	0.15	0.011
27	South Alhayrya	6.99±0.27	5.99±0.36	88.5±7.61	10.54	22.35	0.17	0.013
28	Alhachrage farm A	3.1±0.12	2.01±0.12	65.86±5.67	5.39	11.03	0.08	0.007
29	Alhachrage farm B	7.22±0.28	5.39±0.33	73.1±6.29	9.64	20.53	0.15	0.012
30	Alhachrage C	5.83±0.23	3.67±0.24	53.05±4.56	7.12	15.15	0.11	0.009
31	Alhachrage D	4.14±0.16	2.5±0.16	60.77±5.23	5.95	12.38	0.09	0.007
32	Alhachragestreet	3.89±0.18	1.9±0.14	193.71±16.66	11.02	21.5	0.17	0.013
33	Alhachrage E	5.46±0.22	6.32±0.39	93.68±8.06	10.24	21.69	0.16	0.012
34	Alhachrage F	3.21±0.14	5.05±0.31	91.97±7.91	8.37	17.51	0.13	0.01
35	South Alhachrage A	4.53±0.19	6.53±0.4	53.61±4.61	8.27	17.98	0.13	0.01
36	South Alhachrage B	3.31±0.14	2.3±0.14	69.82±6.01	5.83	11.97	0.09	0.007
37	Galawy A	7.82±0.34	6.63±0.41	72.16±6.21	10.63	22.84	0.17	0.013
38	Galawy B	8.83±0.34	5.64±0.34	88.93±7.65	11.19	23.72	0.17	0.014
39	Galawy C	9.41±0.37	9.28±0.57	87.01±7.48	13.58	29.36	0.21	0.016
40	Alkhldya A	9.29±0.36	7.01±0.44	73.72±6.34	11.6	24.98	0.18	0.014
41	Alkhldya B	13.07±0.5	8.97±0.55	77.42±6.66	14.69	31.85	0.23	0.018
42	Alkhldya C	6.85±0.27	6.83±0.42	77.16±6.64	10.51	22.54	0.17	0.013
43	Alkhldya D	9.76±0.39	10.04±0.61	79.16±6.81	13.88	30.19	0.22	0.017
44	Alkhldya E	3.6±0.14	2.33±0.14	79.66±6.85	6.39	13.05	0.1	0.008
45	Alkhldya F	7.3±0.37	4.84±0.3	92.12±7.92	10.14	21.3	0.16	0.012
46	Alsafala A	4.65±0.18	5.24±0.32	97.93±8.42	9.4	19.67	0.15	0.011
47	Alsafala B	5.34±0.21	3.78±0.23	127.21±10.94	10.05	20.52	0.16	0.012
48	Al gwyga A	4.61±0.19	4.73±0.29	58.47±5.03	7.42	15.86	0.12	0.009
49	Aldera	7.85±0.3	4.61±0.28	53.97±4.64	8.66	18.59	0.13	0.011
Mean		4.35±0.028	3.3±0.033	71.74±7.21	9.54	20.16	0.149	0.0115

Table 2 Mean values of ^{226}Ra, ^{232}Th and ^{40}K for all soil samples under investigation beside other countries.

Country	Activity concentration (Bq/kg)			Reference
	^{226}Ra	^{232}Th	^{40}K	
Tourbh, Saudi Arabia	4.5	3.32	71	Present work
Canada (Saskatchewan)	19	8	480	Kiss., et al., 1988.
Upper Egypt	15.7	16.5	227.5	Abbady et al., 2009
Spain	39	41	578	Quindòs., 1994
Brazil (Rio Grande do Norte)	29.2	47.8	704	Malanca.,et al., 1996
Turkey (Istanbul)	21	37	342	Karahan. and Bayulken, 2000
Denmark	17	19	460	UNSCEAR., 2000
Syrian	20	20	270	UNSCEAR., 2000
South India	35	29.8	117.5	Narayanq .et al., 2001
Jordan (Amman Aqaba Highway)	22-104	21-103	138-601	Al-Jundi ., et al., 2003
Mexico (Zacatecas and Guandalupe)	23	19	530	Mireles *et a*l,. 2003
Cyprus	7.1	5	104.6	Tzortzis.,et al., 2004
Nigeria	16.2	24.4	34.8	Arogunjo., et al., 2004
Bangladesh (Southern districts)	42	81	833	Chowdhury et al. , 2006
Pakistan (Lahore)	25.8	49.2	561.6	Akhtar. et al. , 2005
Vietnam (South- east)	19.6	31	34.6	Huy., and Luyen**,** 2006
Egypt (Farm soil) Nile island's soil	13.7 11.9	12.3 10.5	1233 1636	Ahmed and El-Arabi 2005.





4. Conclusion

Activity levels in the soil of Tourbh, Saudi Arabia have been measured. The mean activity of ^{226}Ra, ^{232}Th and ^{40}K were found to be 4.35±0.028, 3.3±0.033 and 71.74±7.21Bq/kg, respectively. The mean radium equivalent activity Ra_{eq}, representative level index, and terrestrial absorbed dose rate for the area under investigation are 20.16 Bq/kg, 0.149 Bq/kg, and 9.54nGy/h, respectively. The levels of ^{226}Ra, ^{232}Th, and ^{40}K in the soil of the Tourbh were comparatively less than the world average whereas radium equivalent activity, external hazard index, internal hazard index and terrestrial absorbed dose rate were below the recommended limits.

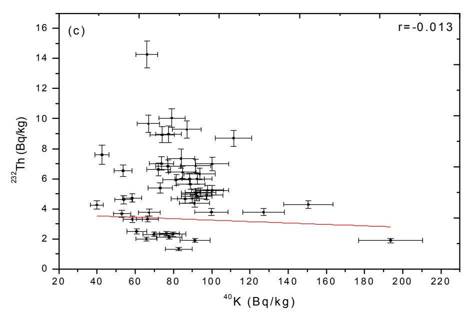


Figure (2) correlations between (a) ^{226}Ra with ^{232}Th, (b)^{226}Ra with ^{40}K and(c) ^{232}Th with ^{40}K

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