Full Length Research Paper

Assessment of Radiological Indices of Soil Samples from Northern Egypt through the Measurement of the Activity Concentrations of Natural Radionuclides

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Abstract

The present work deals with the measurement of concentrations and distributions of natural radionuclide γ-ray activities, produced by ^{40}K, ^{226}Ra, ^{238}U and ^{232}Th, in coastal soils of Koam Mashaal area, Northern Egypt. Besides, the radiation doses that would be delivered to living beings from such soils were calculated. Moreover, external and internal hazard indices, radium equivalents, and annual activities were computed. For this purpose, a total of 57 field samples were collected from the surface till a depth of 50 cm. These samples were analysed using high-purity germanium (HPGe) detector. The concentrations were determined for ^{40}K (range from 114 to 313 $Bqkg^{-1}$), ^{226}Ra (range from 12 to 234.7 $Bqkg^{-1}$), ^{238}U (range from 5.5 to 211 $Bqkg^{-1}$) and ^{232}Th (range from 12.7 to 149.7 $Bqkg^{-1}$), with their mean values reaching 200.68±4.68Bq/kg, 74.18±6.17Bq/kg, 94.25±6.01Bq/kg and 78.12±4.65Bq/kg respectively. Moreover, gamma–absorbed dose rates and radium equivalent activities were calculated for the analyzed samples to assess their radiation hazards arising from them. The annual effective dose equivalent rates in mSv/y due to natural radioactivity was found to be in the range of 0.03 to 0.21 mSv/y with mean 0.12±0.01 mSv/y. The results of the present work were discussed and compared with international recommended values.

Keywords: Y-ray activities, Germanium (HPGe) detector, External hazard indices, Internal hazard indices, Dose rates, Field samples.

INTRODUCTION

Koam Mashaal area is characterized by the occurrence of beach placers that are well known as black-sand deposits. They are derived during flood times from the upper reaches of the River Nile, deposited in the Mediterranean Sea at the outpourings of the delta, and then concentrated by the action of seawater. The mineralogical analyses identified six main minerals accompanied by minor minerals. According to their relative frequencies and economic importance, the six main minerals are: ilmenite, magnetite, zircon, monazite, garnet and rutile. Traces of cassiterite and gold as well as some rare earth elements (REE) in some minerals are also present.

Investigations of radiation dose rates in natural environments are important for community health, as well as radiation protection purposes. The natural radioactivity in soils, which mainly contributes to these dose rates, is due mainly to members of the ^{238}U series,

^{232}Th series and the isotope ^{40}K. These emit energetic and highly- penetrating radiation (known as gamma radiation), which is capable of destroying or causing mutations in cells of living beings (Sitaram and Umawatti, 2002; IAEA, 2003). If exposed to high radioelement concentrations in environment, they could pose community health problems.

The main objectives of this study are focused on determining the distribution of natural radioactivity and calculating γ-ray specific activities of ^{40}K, ^{226}Ra, ^{238}U and ^{232}Th in beach sand samples, collected from Koam Mashaal area, Northern Egypt. The specific activities of ^{40}K, ^{226}Ra, ^{238}U and ^{232}Th in the collected beach- sand samples were estimated through the use of the high-purity Germanium (HPGe) detector. In order to assess radiological hazards due to natural radioactivity associated with these radionuclides, calculations of external and internal hazard indices, absorbed gamma-

ray dose rates in air, and annual effective dose equivalent are presented and discussed. Moreover, the average radium equivalent activity and the annual dose equivalent were calculated and compared with the published results in international literature.

In this context, the present work tries to develop reference data of natural radioactivity for the soil of the area under investigation, and evaluate their radiological consequences if used as building materials. Moreover, this evaluation would also provide a baseline data for estimating the change in environmental radiation. This subject is important in environmental radiological protection, since these sands are widely used as building materials in these districts.

Location of the Study Area

Koam Mashaal area lies on the coastal plain of the Mediterranean Sea, 15 km to the east of Rosetta mouth of the River Nile. It extends for about 3 km and is restricted, between longitudes 30° 32′ 10″ E and 30° 34′ 08″ E and latitudes 31° 26′ 59″ N and 31° 27 ′ 59″ N (Figure 1). The study area reaches about 5.4 km^2 in surface area and is almost covered by beach sands.

Local Geology

Koam Mashaal area is characterized by the occurrence of beach placers that are well known as black-sand deposits. They are derived during flood times from upper reaches of the River Nile, deposited on the Mediterranean Sea coast at the outpourings of the Nile Delta, and then concentrate by the action of seawaters. The sands near the shore are loose and have the same degree of coherence at depth (Naeim et al., 1994). Black sand deposits in the northern Nile Delta, especially in Koam Mashaal area -under study- have received the attention of several researchers, since early 20th century. Those researchers involve Elshazly and Wassef (1984), Elhadary (1998), Abu-Diab (2001) and Bakheit (2004), El-Sadek et al. (2012) and El-Sadek and Elkhatteb (2013).

Sadek et al. (1988) distinguished the following three radiolithological units:
1- A western unit, located at the mouth of Rosetta branch, which is characterized, by the occurrence of shallow lagoons separated from the sea by sand bars.
2- A central unit that is a wide flat terrain of sand deposits, derived by wave action. Lenses, occurring in this unit, have increasing concentrations of black-sands. Sabkha formations frequently occur within these flat deposits. Lacustrine clay layers occur at depths, ranging between 8 m and 10 m and penetrate these deposits.
3- An eastern unit, especially located in the vicinity of Alburullus lagoonal lake, is characterized by the occurrence of aeolian sand dunes accumulated over the flat surface.

The geology of beach sands along the Mediterranean coast is directly related to the development of the River Nile Delta and the past configuration of the River Nile branches. The distribution of beach sands along the coast is controlled mainly by the geomorphological conditions, which vary from west to east (Hammoud, 1966).

Sampling and Laboratory Measurements

From a land area of about 5.4 km^2, 57 representative soil samples were collected from the coastal region for analysis of natural radioactivity. Samples, normally from a depth of 50 cm, were initially dried at room temperature and then in an oven at 85°C for 24 h. After removal of stones and vegetation, the samples were stored for at least one month before the beginning of counting. This was done in order to allow radon (half life 3.8 days) and its short-lived decay daughters (^{214}Bi and ^{214}Pb) to reach secular equilibrium with long-lived ^{226}Ra precursor in the samples. The measurements were carried out in the laboratories of the Nuclear Materials Authority (NMA), Egypt, using a high-purity Germanium (HPGe) detector.

Activity Concentrations

Under the assumption that secular equilibrium was reached between ^{226}Ra and its short-lived daughters, γ-ray transitions to measure concentrations of the assigned nuclides in the series are as follows:

^{238}U activities of soil samples, under investigation, were derived from weighted means of the photopeaks of ^{234}Th (63.3, 92.4, and 92.8 keV). ^{226}Ra activity was determined by taking the mean activity of the three separate photopeaks of its daughter nuclides: ^{214}Pb at (295.2 and 352.0 keV), and ^{214}Bi at (609.3 keV). For ^{232}Th determination, the photopeak of ^{228}Ac (at 911.1 keV) and the photopeaks of ^{212}Pb (at 583.1 keV) and 208Tl (at 238.6 keV) were used. 40K was directly determined using the 1460.8 keV photopeak.

RESULTS AND DISCUSSION

In total, 57 samples were measured and their contents of radionuclides were determined. Table (1) gives an overall view of the results. It contains the relevant parameters of the samples which include: identification serial number, location by UTM, activity of ^{226}Ra, in Bq/kg, and Ueq, Theq and K contents in Bq/kg. The

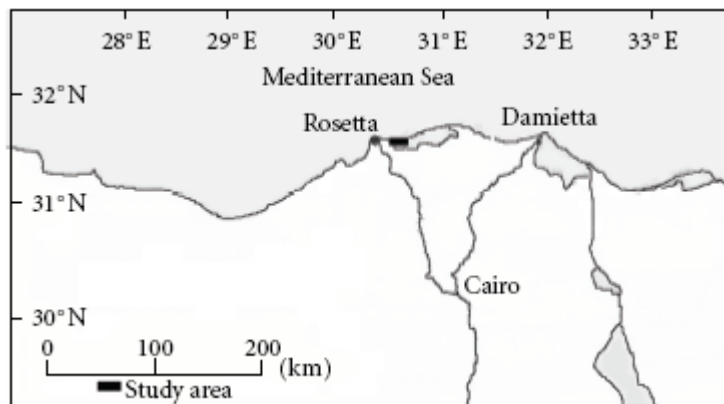Sample Numbers

Figure 1. Map of Northern Egypt showing the location of Koam Mashaal area.

Table 1. Activity concentrations of the three natural radionuclides, in Bqkg^{-1}, in the 57 studied soil samples, Koam Mashaal area, Northern Egypt.

Ser. No.	Location		^{226}Ra (Bqkg $^{-1}$)	^{238}U (Bqkg $^{-1}$)	^{232}Th (Bqkg $^{-1}$)	^{40}K (Bqkg $^{-1}$)
1	265900	3482200	38.6	62	49.7	223
2	265900	3482600	51	55	78	222
3	265900	3483150	13.7	17	12.7	313
4	266200	3482000	40	72	53.7	177
5	266200	3482150	13	11	15	262
6	266200	3482400	70.7	90	101.7	183
7	266200	3482600	60	136	87.3	195
8	266300	3483050	102.3	87.8	84.1	215.9
9	266500	3482000	62.7	117	111.3	163
10	266500	3482200	22.7	51	29	237
11	266500	3482400	93.3	211	105	156
12	266500	3482600	76.7	117	119	163
13	266800	3482150	72.3	174	89	166
14	266800	3482300	36	98	81	256
15	266800	3482600	12	10	14	258
16	266800	3482850	40.6	98	60.3	114
17	266800	3483000	92.6	148	149.7	205
18	266800	3483200	35.7	71	59.3	221
19	266800	3483300	22.7	79	36.7	210
20	266800	3482000	106.1	63.8	71	160.5
21	267100	3482600	64	81	95.5	204
22	267100	3482750	66.7	75	92.3	181
23	267100	3483350	56	115	97.7	226
24	267400	3482450	16.3	10	37	248
25	267400	3483250	79	151	146.3	218
26	267400	3483450	52	109	103.3	224
27	267400	3482200	147.5	99.7	92	177.5
28	267400	3483050	140.2	126.3	146	183.7
29	267700	3482200	74	136	100	201
30	267700	3482500	25.7	92	39	233
31	267700	3483000	77.7	133	114.3	184
32	267700	3483500	45.3	137	66.3	216
33	267700	3482350	150.3	113.1	82.7	160.9
34	268000	3482200	80.7	121	117.7	161
35	268000	3482800	68	127	113.3	168

Table 1. Continue

36	268000	3483000	56	161	91.7	181
37	268000	3482400	144.3	102.8	81.4	179.6
38	268000	3483550	67.8	55	54.7	236.3
39	268300	3483100	43.7	93	59.3	169
40	268300	3483650	32.7	49	56.7	207
41	268300	3482950	172.7	117.8	115.6	166.6
42	268300	3483400	234.7	124	130	197.7
43	268300	3482400	141.8	82.1	69.7	170.4
44	268300	3482700	74.3	5.5	37.9	212.2
45	268600	3482800	80.7	187	140	168
46	268600	3483500	21	68	26	229
47	268600	3483200	62.7	71	98.7	175
48	268600	3482000	125.5	80	72.5	158
49	268600	3483000	150	97.8	97.5	188.3
50	268600	3483750	66.2	165.6	50.1	222.7
51	269000	3482200	36	47	45.3	234
52	269000	3482600	60.7	104	79.7	187
53	269000	3482800	21.7	29	25.7	251
54	269000	3482400	128.4	98.7	76.3	167.7
55	269000	3483000	62.6	46	40.8	192.7
56	269000	3483650	142	123.2	100.8	218.6
57	269000	3483850	97.1	70	51.6	240.5
Min.			12	5.5	12.7	114
Max.			234.7	211	149.7	313
M.			66.2	97.8	81	197.7
X.			74.18	94.25	78.12	200.68
X±S. E.			74.18±6.17	94.25±6.01	78.12±4.65	200.68±4.68

Min. = Minimum   Max. = Maximum   X. = Mean   M. = Median   S. E. = Standard Error

concentrations (or activities) are then converted into doses.

Activity concentrations of ^{40}K, ^{226}Ra, ^{238}U and ^{232}Th radionuclides in soils collected from the study area are plotted on Figure (2). All values are reported as Bq kg^{-1} dry weight. As can be seen from Figure (2) and Table (1), the concentrations of ^{226}Ra, ^{238}U and ^{232}Th seem to be –more or less- homogenously distributed allover the investigated area. Table (1) presents a statistical summary for the measured activities in all the 57 samples. The lowest concentrations of ^{40}K and ^{226}Ra are found to be 114 and 12 Bq kg^{-1}, respectively, whereas their highest concentrations reach 313 and 234.7 Bq kg^{-1}, respectively. On the other hand, the concentrations of ^{238}U and ^{232}Th vary from 5.5 to 211 and from 12.7 to 149.7 Bq kg^{-1}, respectively. Arithmetic mean values for ^{40}K, ^{226}Ra, ^{238}U and ^{232}Th activity concentrations, as calculated for all soil samples, were found to be 200.68 ± 4.68, 74.18 ± 6.17, 94.25 ± 6.01 and 78.12 ± 4.65 Bq kg^{-1}, respectively. It can be seen that ^{40}K almost always contributes to the most specific activity compared to ^{226}Ra, ^{238}U and ^{232}Th. Table (3) shows the concentrations of average natural radionuclides in soil and absorbed doses in air as published for different parts of the world (UNSCEAR, 2000), compared with those of the present area of study.

Environmental Impact of the Radionuclides

Direct external exposure to radiations, inhalation and ingestion represent the main and most common pathways by which some environmental impacts may be caused. This depends on several factors including; type and energy of radiations, their total doses, size of irradiation section, radio-sensitivity and age of the individual (Rumyantsev, 1967). Several methods are proposed to estimate and discuss the environmental impacts of radiations (IAEA, 1979; ICRU, 1980; Grasty et. al, 1984, Yu et al., 1992; Tufail et al., 1992; UNSCEAR, 2000; Baykara, et al., 2009; Taskin et al., 2009 ; Baykara et al., 2011; Moharram et al., (2011); Agnieszka, 2012; Nursama et al., 2013).

In the present study, the expected environmental impacts of the radionuclides in soil on individuals are investigated and discussed as follows:

1- Radium Equivalent Activity (Ra$_{eq}$):

The distribution of ^{226}Ra, ^{232}Th and ^{40}K in environment is not uniform. Therefore, a common radiological index was introduced to evaluate the actual activity level of ^{40}K, ^{226}Ra, ^{238}U and ^{232}Th in samples and radiation hazards associated with these radionuclides. This index is usually known as radium equivalent activity (Beretka and Mathew, 1985).
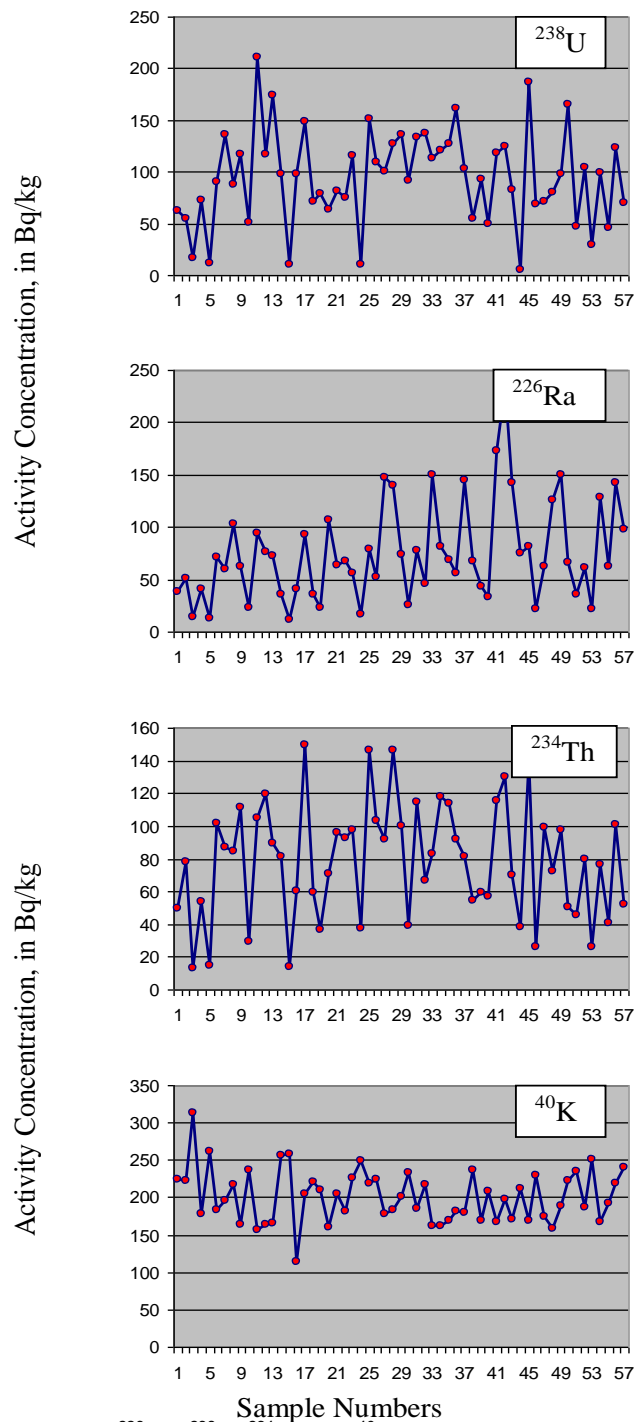
Figure 2. ^{226}Ra, ^{238}U, ^{234}Th and ^{40}K activity concentration, in Bqkg-1, for the 57 studied soil samples, Koam Mashaal area, Northern Egypt.

Table 2. Radium equivalent (R_{eq}), absorbed dose rate (D), effective dose rate (E), external hazard index (H_{ex}) and internal hazard index (H_{in}) of the 57 studied soil samples, Koam Mashaal area, Northern Egypt.

Sample Number	Ra_{eq} (Bq/kg)	D (nGy/h)	$E_{outdoor}$ (mSv/y)	E_{indoor} (mSv/y)	H_{ex} (mGy/y)	H_{in} (mGy/y)
1	126.8	68.0	0.08	0.33	0.34	0.44
2	179.6	81.9	0.10	0.40	0.48	0.62
3	55.9	28.7	0.04	0.14	0.15	0.18

Table 2. Continue

4	130.4	73.1	0.09	0.35	0.35	0.46
5	54.6	25.1	0.03	0.12	0.14	0.18
6	230.2	110.7	0.14	0.54	0.62	0.81
7	199.8	123.7	0.15	0.60	0.53	0.70
8	239.2	100.4	0.12	0.49	0.64	0.92
9	234.4	128.1	0.16	0.62	0.63	0.80
10	82.4	51.0	0.06	0.25	0.22	0.28
11	255.5	167.5	0.21	0.82	0.69	0.94
12	259.4	132.7	0.16	0.65	0.70	0.90
13	212.4	141.1	0.17	0.69	0.57	0.76
14	171.5	104.9	0.13	0.51	0.46	0.56
15	51.9	23.9	0.03	0.11	0.14	0.17
16	135.6	86.5	0.11	0.42	0.36	0.47
17	322.5	167.4	0.21	0.82	0.87	1.12
18	137.5	77.9	0.10	0.38	0.37	0.46
19	91.4	67.5	0.08	0.33	0.24	0.30
20	219.9	79.1	0.10	0.38	0.59	0.88
21	216.3	103.7	0.13	0.50	0.58	0.75
22	212.6	98.0	0.12	0.48	0.57	0.75
23	213.1	121.6	0.15	0.59	0.57	0.72
24	88.3	37.4	0.05	0.18	0.23	0.28
25	304.9	167.3	0.21	0.82	0.82	1.03
26	216.9	122.2	0.14	0.59	0.58	0.72
27	292.7	109.1	0.13	0.53	0.79	1.18
28	363.1	154.2	0.19	0.75	0.98	1.35
29	232.5	131.7	0.16	0.64	0.62	0.82
30	99.4	75.8	0.09	0.37	0.26	0.33
31	255.3	138.2	0.16	0.67	0.68	0.89
32	156.7	112.4	0.13	0.55	0.42	0.54
33	280.9	108.9	0.13	0.53	0.75	1.16
34	261.4	133.7	0.16	0.65	0.70	0.92
35	242.9	134.2	0.16	0.65	0.65	0.83
36	201.1	137.3	0.16	0.67	0.54	0.69
37	274.5	104.2	0.12	0.51	0.74	1.13
38	164.2	68.3	0.08	0.33	0.44	0.62
39	141.5	85.8	0.10	0.42	0.38	0.50
40	129.7	65.5	0.08	0.32	0.35	0.43
41	350.8	131.2	0.16	0.64	0.94	1.41
42	435.8	144.1	0.17	0.70	1.17	1.81
43	254.6	87.1	0.10	0.42	0.68	1.07
44	144.8	34.3	0.04	0.16	0.39	0.59
45	293.8	178.0	0.21	0.87	0.79	1.01
46	75.8	56.7	0.06	0.27	0.20	0.26
47	217.3	99.7	0.12	0.48	0.58	0.75
48	241.3	87.3	0.10	0.42	0.65	0.99
49	303.9	111.9	0.13	0.54	0.82	1.22
50	154.9	116.1	0.14	0.56	0.41	0.59
51	118.8	58.9	0.07	0.28	0.32	0.41
52	189.1	104.0	0.12	0.51	0.51	0.67
53	77.8	39.4	0.04	0.19	0.21	0.26
54	250.4	98.7	0.12	0.48	0.67	1.02
55	135.8	53.9	0.06	0.26	0.36	0.53
56	302.9	126.9	0.15	0.62	0.81	1.20
57	189.4	73.6	0.09	0.36	0.51	0.77
Minimum	51.8	23.912	0.03	0.12	0.14	0.17
Maximum	435.8	178.01	0.21	0.87	1.18	1.81
Mean±S.E.	**201.3±11.2**	**99.15±5.10**	**0.12±0.01**	**0.49±0.03**	**0.54±0.03**	**0.74±0.05**

Ra_{eq} (Bq kg^{-1}) = A_{Ra} + 1.43 A_{Th} + 0.077A_K ……….. (1)
        Where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K respectively. In the definition, it is assumed that 10 Bq kg^{-1} of ^{226}Ra, 7 Bq kg^{-1} of ^{232}Th and 130 Bq kg^{-1} of ^{40}K produce an equal gamma ray dose (Krisiuk et al., 1971 and Stranden, 1976). The calculated values of Ra_{eq} for all 57 studied samples are shown in Table (2). The calculated Ra_{eq} values range from 51.9 to 435.8 Bq kg^{-1} with an arithmetic mean of 201.3 ± 11.2 Bq kg^{-1}. The results of this study show that the mean value of Ra_{eq}, obtained for building materials, attains 201.3 ± 11.2 Bq kg^{-1} which is far less than the recommended value (370 Bq kg^{-1}) (UNSCEAR, 1988;2000). Therefore, such value does not pose a radiological hazard, when used for construction of buildings. From Table (3), it is observed that the mean value of this work is higher than the published value of the worldwide mean (121 Bq kg^{-1}).

2- Evaluation of Annual Effective Dose Rate (E) and Absorbed Dose Rate (D):

        To estimate the annual effective doses rate (E), account must be taken of:
(a) the conversion coefficient from absorbed dose in air to effective dose and,
(b) the indoor and outdoor occupancy factors.
        The annual estimated average effective dose equivalent received by a member is calculated using a conversion factor of 0.7 SvGy^{-1}, which is used to convert the absorbed rate to human effective dose equivalent with an outdoor occupancy of 20% and 80% for indoors. The annual effective doses rate in units of milliSievert/year, are determined as follows (Beck, 1972; UNSCEAR, 2000):

E_{Indoor} (mSv/y) = Absorbed Dose (D) nGyh^{-1} x 8760 h x 0.8 x 0.7 SvGy^{-1} X 10^{-6} …………………………………… (2)

$E_{Outdoor}$ (mSv/y) = D (nGyh^{-1}) x 8760 h x 0.2 x 0.7 SvGy^{-1} X 10^{-6} …………...........................……… (3)

        Where 0.2 and 0.8 are the outdoor and indoor occupancy factor adopted by UNSCEAR (2000) and 0.7 SvGy^{-1} for the conversion coefficient from gamma absorbed dose rate in air (D), defined as given in equation (4), to effective dose received by adults. However, dose rate (D) in nanoGray per hour at a height of 1.0 m above the ground was calculated by the following equation (Beck 1972; UNSCEAR, 2000):
D(nGyh^{-1}) = 0.462 C_U^{238} + 0.604 C_{Th}^{232} + 0.0432 C_K^{40} ………………………………………………....... (4)
where C_U^{238}, C_{Th}^{232} and C_K^{40} are the activity concentration of ^{238}U, ^{232}Th and ^{40}K in Bqkg^{-1}, respectively. Columns (3, 4 and 5) of Table (2) give the results of these calculations (D, E_{indoor} and $E_{outdoor}$) for the area under investigation.
        In the present study, D values were found to vary from 23.91 to 178.01 nGy h^{-1} (Table 2). The average value of the absorbed dose rate in air for the entire area is found to be (99.15) nGyh^{-1}. According to UNSCEAR (2000), the mean dose rate in air outdoors from terrestrial gamma-rays in normal circumstances is about 57 nGyh^{-1} (Table 3), while the worldwide average annual effective dose is approximately 2.4 mSvy^{-1}. Figure (3) illustrates the measured relative contribution to the dose rate outdoors for all samples. The relative contribution to dose due to ^{40}K is 60%, followed by a lower contribution due to ^{238}U, ^{232}Th and ^{226}Ra series (17%, 13% and 10%) respectively.

        The corresponding indoor and outdoor annual effective doses range from 0.12 to 0.87 mSv and 0.03 to 0.22 mSv with an average values of 0.49 and 0.12 mSv respectively (Table 2). Meanwhile, the world wide average annual effective dose is approximately 0.5 mSv. The results for individual countries being generally within the 0.3- 0.6 mSv range for indoors. The results of the study area for average annual effective dose are within the range of worldwide average value. Figures (4 and 5) represents the distribution of the annual effective dose rate (outdoor and indoor) for full utilization of the 57 measured soil samples.

3- External and Internal Hazard Indices (H_{ex} and H_{in})

        The external hazard index (H_{ex}) is used to measure the external hazard due to emitted gamma radiation. It is calculated by the following equation (Krieger, 1981) as:
H_{ex} = A_{Ra} / 370 + A_{Th} / 259 + A_K / 4810 ……………… (5)
where H_{ex} is the external hazard index, and A_{Ra}, A_{Th} and A_K are the specific activities of Ra, Th and K in Bqkg^{-1} respectively.
H_{ex} must not exceed the limit of unity for the radiation hazard to be negligible.
The internal hazard index (H_{in}) gives the internal exposure to carcinogenic radon and its short-lived progeny and is given by the following formula ((Beretka and Mathew, 1985):
        H_{in} = A_{Ra} / 185 + A_{Th} / 259 + A_K / 4810 ………. (6)
where H_{in} is the internal hazard index, and A_{Ra}, A_{Th} and A_K are the specific activities of Ra, Th and K in Bqkg^{-1} respectively. The values of H_{in} must also be less than unity to have negligible hazardous effects of radon and its short-lived progeny to the respiratory organs (UNSCEAR, 2000).

        The calculated H_{ex} and H_{in} values range from 0.14 to 1.17 and from 0.17 to 1.8, respectively (Table 2). However, the mean values of H_{ex} and H_{in} are found to be 0.54 ± 0.03 and 0.74 ± 0.06, respectively. As can be seen, the average values do not, in general, exceed the permissible recommended limits, indicating that the hazardous effects of these radiations are negligible.

CONCLUSIONS

The activity levels and distribution of natural terrestrial radionuclides of ^{40}K, ^{226}Ra, ^{238}U and ^{232}Th were measured by a high-purity germanium (HPGe) detector for the 57 soil samples collected from surface till a depth

Table 3. Concentrations of the average three natural radionuclides in soil, absorbed doses in air and radium equivalent activities from different parts of the world (UNSCEAR, 2000), compared with those of the present study.

Country	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	D (nGy/h)	Radium equivalent activity (Bq/kg)
Belgium	26	27	380	43	94
Bulgaria	45	30	400	70	119
China	32	41	440	62	125
Denmark	17	19	460	52	80
Greece	25	21	360	56	83
Hong Kong	59	95	530	87	236
India	29	64	400	56	151
Iran	28	22	640	71	109
Japan	33	28	310	53	97
Luxembourg	35	50	620	49	154
Poland	26	21	410	45	88
Portugal	44	51	840	84	182
Romania	32	38	490	59	124
Spain	32	33	470	76	115
Switzerland	40	25	370	45	104
USA	40	35	370	47	119
Worldwide mean	**33**	**36**	**474**	**57**	**121**
Present study area	**95**	**78**	**201**	**99**	**201**
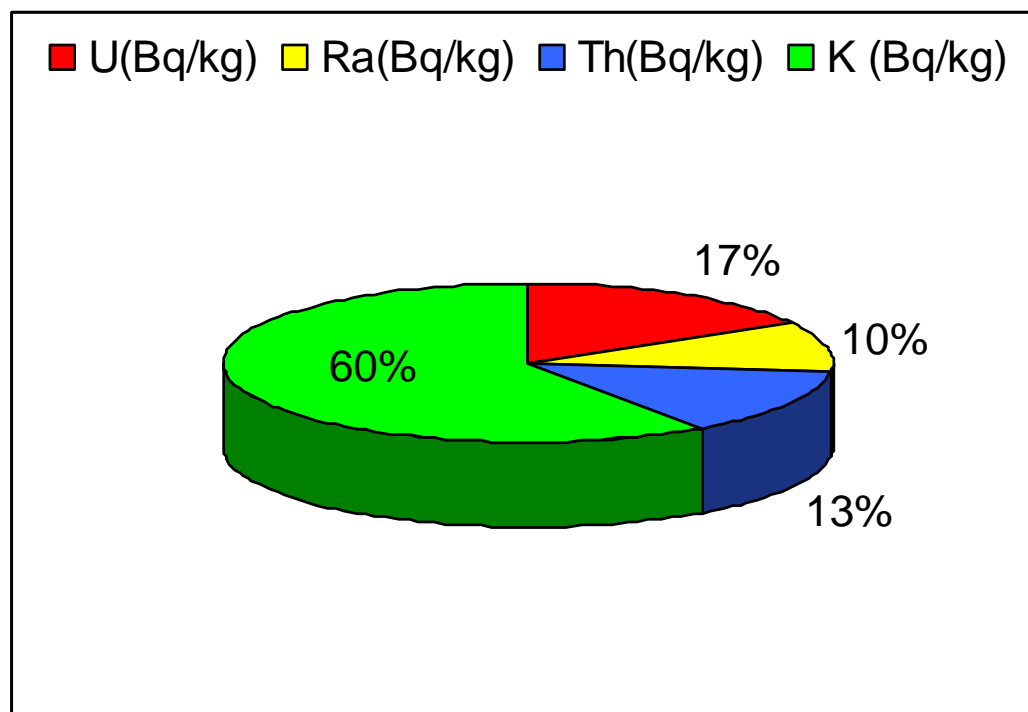
Figure 3. Relative contributions to total absorbed dose rates in air due to Uranium (^{238}U), Thorium (^{232}Th), Potassium (^{40}K) and Radium (^{226}Ra), in Bq kg^{-1}, for the 57 studied soil samples, Koam Mashaal area, Northern Egypt.
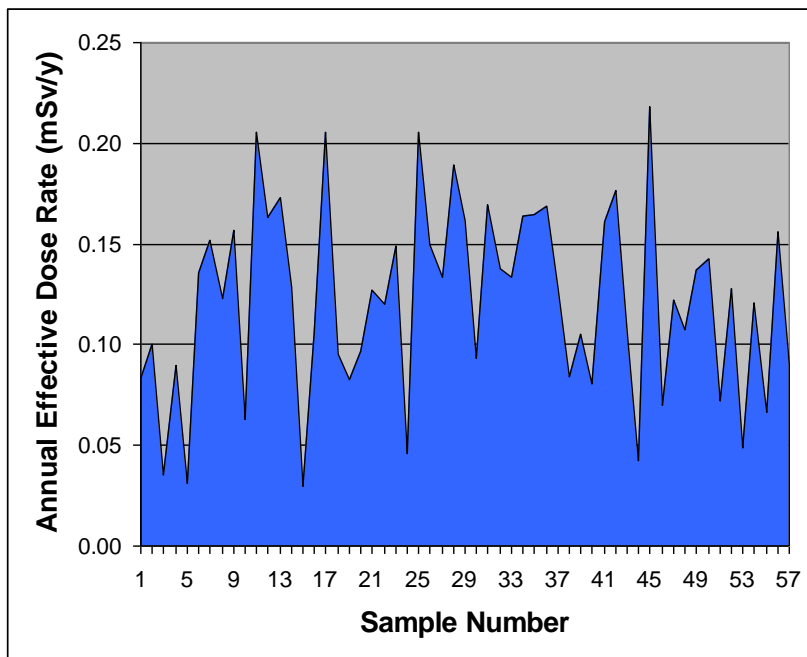
Figure 4. Frequency distribution of the Annual effective dose equivalent rate (outdoor) for full utilization of the 57 measured soil samples, Koam Mashaal area, Northern Egypt.
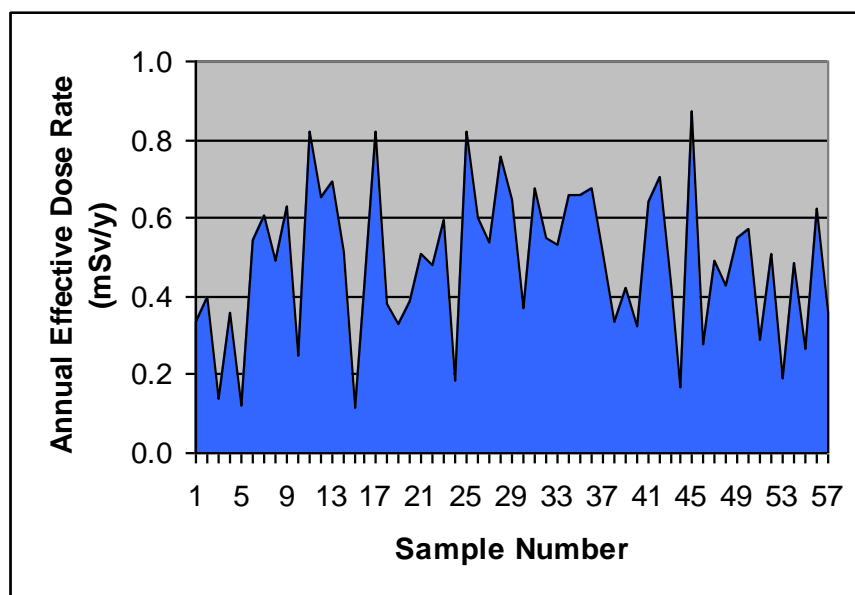

Figure 5. Frequency distribution of the Annual effective dose equivalent rate (indoor) for full utilization of the 57 measured soil samples, Koam Mashaal area, Northern Egypt.

reaching 50 cm. The extracted values are, in general, comparable with the corresponding ones obtained from other countries. It can be observed that all the activity concentrations of the mean two natural radionuclides (^{238}U and ^{232}Th) were found to be higher than the average worldwide ranges. Meanwhile, ^{40}K activity concentrations were found to be lower than the average

worldwide ranges. Thus, the background of the study area was found to exceed the background range of the upper part of the Earth's crust. In this context, the median activities of ^{40}K, ^{226}Ra, ^{238}U and ^{232}Th indicate that ^{40}K is the dominant gamma-emitting source in the soil of this area.

The result of this study showed that, the mean value

of Ra_{eq} attains 201.4 ± 11.2 $Bqkg^{-1}$, which far less than the international recommended value (370 $Bqkg^{-1}$). The mean absorbed dose rate in air (99.15 $nGyh^{-1}$) in the study area was found to be higher, when compared with the worldwide average value (57 $nGyh^{-1}$). Moreover, the corresponding indoor and outdoor annual effective doses range from 0.12 to 0.87 mSv and 0.03 to 0.22 mSv, with mean values of 0.49 and 0.12 mSv respectively. Meanwhile, the worldwide average annual effective dose is approximately 0.5 mSv. Consequently, the mean values of H_{ex} and H_{in} are found to be 0.54 ± 0.03 and 0.74 ± 0.06, respectively which are less than the limit of unity.

In regard to the results of the above radiation hazard parameters, the use of these materials in construction of dwellings is considered to be safe for inhabitants. 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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