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Assessment of Natural Radioactivity of Soil Sample in Selected Locations of Basrah Governorate

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Abstract The concentration levels of ^{226}Ra, ^{232}Th and ^{40}K in soil have a great concern in the recent decades, due to its effect on the human health. The radioactivity of some soil samples taken from selected locations in Basrah Governorate have been measured using a NaI(Tl) detector based on gamma ray spectroscopy. Radium equivalent activity, external and internal hazard indices associated with the natural radionuclide were calculated to assess the radiation hazard of the natural radioactivity on the occupiers. The present investigation shows that the level of natural radioactivity for ^{232}Th and ^{40}K in such soil is well below the acceptable limits, while ^{226}Ra is higher. From the analysing the results, it was found that soil in the area does not possess any health hazard to the inhabitant.

Keywords: *natural radioactivity, Basrah Governorate, NaI(Tl) detector, Radium equivalent activity*

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1. Introduction

Humans are primarily exposed to radiation from the sun, cosmic rays and naturally-occurring radioactive elements (NORM) found in the earth's crust. Nearly in all nations, scientists probed since long time ago and are still probing the earth's crust and for a long time in the future to measure the radiation levels and quantify the hazards and doses affecting people, animals, plants and all kinds of life [1].

Human activities, such as a nuclear reactors and nuclear bomb testing are produced radionuclides and they called technical enhanced radioactive elements (TENORM). Some radionuclides, such as radium, uranium, thorium and potassium have existed since the formation of the earth. Natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological and geographical conditions. They appear at different levels in soil of each region in the world [2,3,4]. Since the distribution of radioactive nuclei in the environment is random, the knowledge of their distribution in soil plays an important role in radiation protection and measurements [5]. The main contributor of radiation exposure is the emanation of Radon gas from soil, the progeny of ^{226}Ra [6]. The sources of the radiations are terrestrial, extraterrestrial and anthropogenic. The radiation of terrestrial origin comes from various earthly materials which contain various amounts of 238U and 232Th and their decay products and ^{40}K. The level of radiation in any area depends on local geological conditions. Higher radiation levels are associated with igneous rocks, such as granite, granodiorites and syenites, and lower levels with sedimentary rocks with some exceptions where shales and phosphate rocks are a source of high radiation [7]. Assessment of radionuclides in soils and rocks in many parts of the world has been on the increase in the past two decades because of their hazard on the health of the populace . While this is the case, the research into natural radionuclide in the soils and rocks of Southern-Iraq is yet to receive the much needed attention compared to the rate of ordinary soil due to the increases of oil production in the area and processing being done in the region. As a contribution to focus on this area, a number of radiological indices were measured from on samples taken from oil field of Basrah.

The main objective of this study is to determine activity concentration of natural radionuclides in soil of selected area in Basrah Governorate. The radium equivalent, activity utilization indices and effective absorbed dose were calculated and compared with international available data.

2. Material and methods

2.1. Study Area

The area of study, shown in Figure 1, represent southern part of Basrah Governorate, which is considered as contaminated area due to the fallout ash during the Allies war on Iraq.

2.2. Sample Collection and Preparation

Soil were collected at each sampling location from different depth. About 500-600 gm of each sample was crushed into fine powder, and fine quality of the sample

was obtained using scientific sieve. Samples were heated in the oven at 110°C for 24h to remove moisture, put inside Marinalli beakers and then stored for 30 days to allow the equilibrium between ^{226}Ra and ^{222}Rn. The activity concentration of ^{226}Ra, ^{228}Ra, ^{238}U, ^{232}Th and ^{40}K was estimated from the gamma spectrum using Na(Tl) detector 3x3 inch with a 1024 channel computer analyzer USX supplied by Spectrum Technique Company. The detector was employed with lead shielding, 4 cm thickness, which reduced the background. The detector was calibrated using standard sources of ^{57}Co (peak 122 keV), ^{137}Cs (peak 662 keV) and ^{60}Co (peaks 1173, 1333 keV). The detector resolution is about 8% at 662 keV of ^{137}Cs. The efficiency calibration was achieved using eight standard sources include the calibration sources. The system was running freely, for 12 h live time, to evaluate the background spectrum. The Marinalli beaker contains sample was placed over the detector for counting.

Activity concentration A_i of any gamma-rays line taken to represent this parameter for the environmental radionuclides has been calculated using the relation [8]

$$A_i = \frac{Net\,count}{\varepsilon \times I_\gamma \times M \times t} \quad (1)$$

where ε is absolute gamma peak efficiency of the detector at this particular gamma-ray energy, I_γ decay intensity for the specific energy peak (including the decay branching ratio information), M the mass of the sample in kg and t is the counting time of the measurement in second.

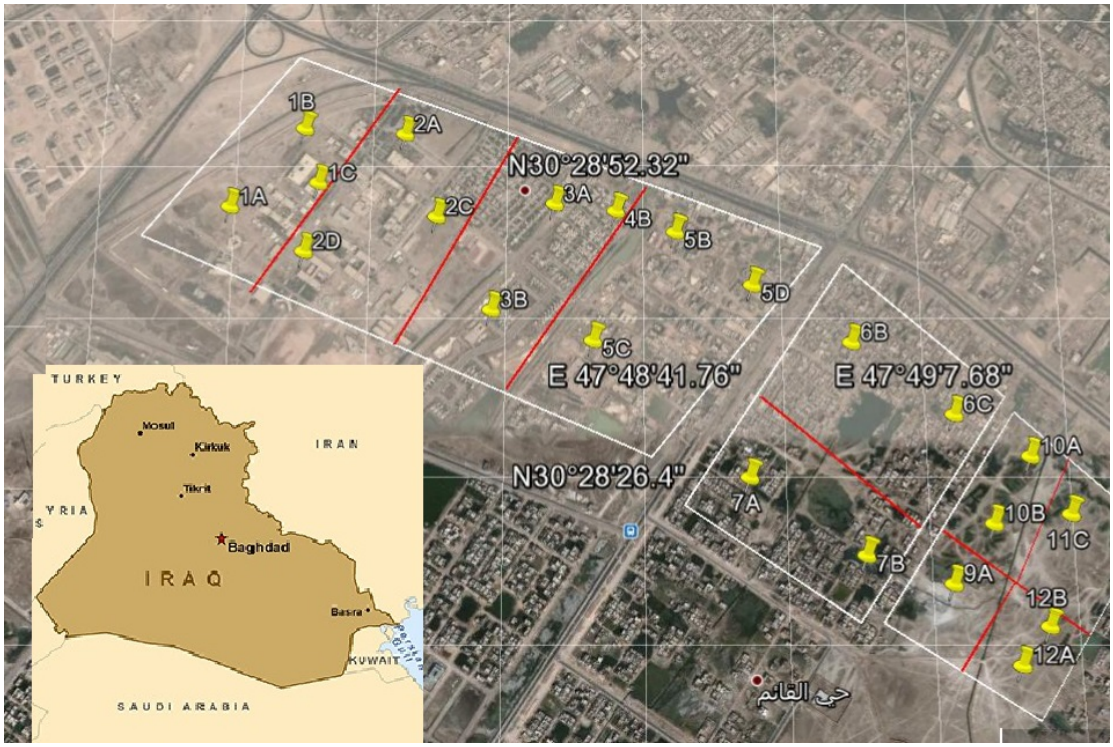

Figure 1. The studied area in Basrah governorate, southern part of Iraq

To evaluate activity concentrations of natural radionuclides, one has to recognized the belong city of each peak according to gamma decay of each isotope [9]. For ^{226}Ra we are looking for the gamma ray lines 295 keV(19.2%), 352 keV (37.1%), 609 keV (46.1%), 1120 keV (15%) and 1760 keV (15.4%). The peak of 186 keV assumed to be from ^{235}U since it has slight effect on the total concentration after subtracting the background, 42.8% for Ra and the rest for ^{235}U. The determination of existence of ^{232}Th was achieved by 338 keV (12%), 911 keV (29%), 964 keV (5.05%) and 969 keV (17%). The case of ^{238}U is recognized by 1001 keV (83%), 766 keV (29%) and 2204 keV (5%). For ^{40}K, this directly determined using 1460 keV (10%) peak.

3. Calculation of Activities, Hazard Indices and Dose Parameters

The exposure due to gamma- radiation is usually defined in term of radium equivalent activity (Ra_{eq}). Radium equivalent activity is used to assess the hazards associated with materials that contain ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}, which is, determined by assuming that 370 Bq kg^{-1} of ^{226}Ra or 260 Bq kg^{-1} of ^{232}Th or 4810 Bq kg^{-1} of ^{40}K produce the same γ dose rate. The Ra_{eq} of a sample in (Bq kg^{-1}) can be achieved using the following relation [10];

$$Ra_{eq} = (A_{Ra}) + (A_{Th} \times 1.43) + (A_K \times 0.077) \quad (2)$$

The published maximal permissible Ra_{eq} is 370 Bq kg^{-1} [11].

The external and internal hazard indices are an evaluation of the hazard of the natural gamma radiation. The prime objective of this index is to limit the radiation dose to the admissible permissible dose equivalent limit around 1mSvy^{-1}. In order to evaluate this index, one can use the following relations [10]

$$H_{ex} = (A_{Ra}/370) + (A_{Th}/259) + (A_k/4810) \le 1 \quad (3)$$

$$H_{in} = (A_{Ra}/185) + (A_{Th}/259) + (A_k/4810) \le 1 \quad (4)$$

In order to estimate the annual effective dose rate in air, the conversion coefficient from absorbed dose in air to effective dose received by an adult must be considered. This value is published in UNSCEAR 2000 and UNSCEAR 1993, to be 0.7 $SvGy^{-1}$ for environmental exposure to gamma rays of moderate energy. The outdoor occupancy factor is about 0.2 [9]. The annual effective dose equivalent is given by the following equation [10];

$$E\left(mSv/y\right) = D(nGy/h)\times 8760(h/y) \times n\times 0.7(Sv/Gy)\times 10^{-6} \quad (5)$$

where

$$D\left(\frac{nGy}{h}\right) = 0.0417A_K + 0.462A_{Ra} + 0.606A_{Th} \quad (6)$$

and n=0.2 for outdoor and 0.8 for indoor.

The world average annual effective dose equivalent (E) from outdoor or indoor terrestrial gamma radiation only is 0.560 mSv/y [UNSCEAR].

4. Results and Discussions

The measured values of natural radioactivity concentration for ^{226}Ra, ^{232}Th, ^{238}U and ^{40}K for different location of southern part of Basrah Governorate, Iraq are given in Table 1. The worldwide average activity concentration for ^{226}Ra, ^{232}Th and ^{40}K reported by UNSCEAR are 50 Bq kg^{-1}, 27 Bq kg^{-1}, 400 Bq kg^{-1} respectively. From Table 1; the activity concentration of ^{226}Ra ranges from 8.0±2.9 Bq kg^{-1} to 197±16.8 Bq kg^{-1} with average value of 84.0±7.7Bq kg^{-1}, which is higher than the recommended limit of UNSCEAR. The specific activity of ^{232}Th ranged from 2.1±0.1Bq $kg^{-1}$to 12.0±0.5 Bq kg^{-1}, with average value of 8.2±1.0 Bq kg^{-1}. The range of activity for ^{40}K is from 57.0±2.9 Bq kg^{-1} to 635.0±18.3 Bq kg^{-1} and average value is 315±9 Bq kg^{-1}. Both average value for ^{232}Th and ^{40}K are below the recommended limit of UNSCEAR.

Table 1. The values ^{226}Ra, ^{232}Th and ^{40}K specific activity concentrations using gamma ray spectroscopy of soil samples from Basrah Governorate. The letters a, b, c and d are closed locations

S. ID	^{226}Ra Bq/kg	^{232}Th Bq/kg	^{40}K Bq/kg
1a	67.0±7.1	11.0±0.5	283.0±7.6
1b	156.0±7.0	9.9±0.4	295.0±0.3
1c	74.0±7.4	10.3±0.5	477.0±7.6
2a	38.0±0.3	5.7±0.1	181.7±7.2
2c	99.0±6.5	11.0±0.4	294.6±7.0
2d	30.0±2.7	5.1±0.5	48.0±8.3
3a	12.0±3.2	9.1±0.4	110.0±4.0
3b	103.0±16.0	7.3±1.1	254.0±15.9
4b	76.5±6.8	7.0±0.4	188.7±6.6
5b	112.8±14.1	6.8±0.9	331.0±14.8
5c	37.3±5.2	3.9±0.9	635.0±18.3
5d	54.0±14.3	7.9±0.9	486.0±18.0
6b	105.0±3.0	12.0±0.5	246.0±7.7
6c	99.3±3.8	10.2±0.4	262.0±7.9
7a	113.9±6.5	1.6±0.2	272.0±15.0
7b	68.6±16.2	10.4±0.1	583.0±19.1
9a	8.0±2.9	2.1±0.1	57.0±2.9
10a	98.0±8.0	9.6±0.5	370.0±9.3
10b	94.0±7.5	8.5±0.5	290.0±8.0
11c	123.0±7.8	12.0±0.5	433.0±9.3
12a	197±16.8	9.0±1.1	366.0±17.5
12b	82.0±17.0	10.5±1.1	415.0±18.0

From the table one can see that the maximum value of ^{226}Ra is 197±16.8 Bq/kg and minimum value is 8.0±2.9 Bq/kg with average value 88.9 Bq/kg. The maximum value of ^{232}Th is 12.0 Bq/kg and minimum is 1.6 Bq/kg with average value 8.4 Bq/kg. While in the case of ^{40}K the maximum value is 635.0±18.3 Bq/kg and minimum is 57.0±2.9 Bq/kg. All the results obtained were in the range of other workers in the same area, but in different locations [12,13,14]. No uniform trend in the variation of concentration of natural radionuclides found in the soil samples as can be seen from Figure 2. This figure shows no correlation between ^{226}Ra and ^{40}K and positive weak correlation between ^{226}Ra and ^{232}Th.

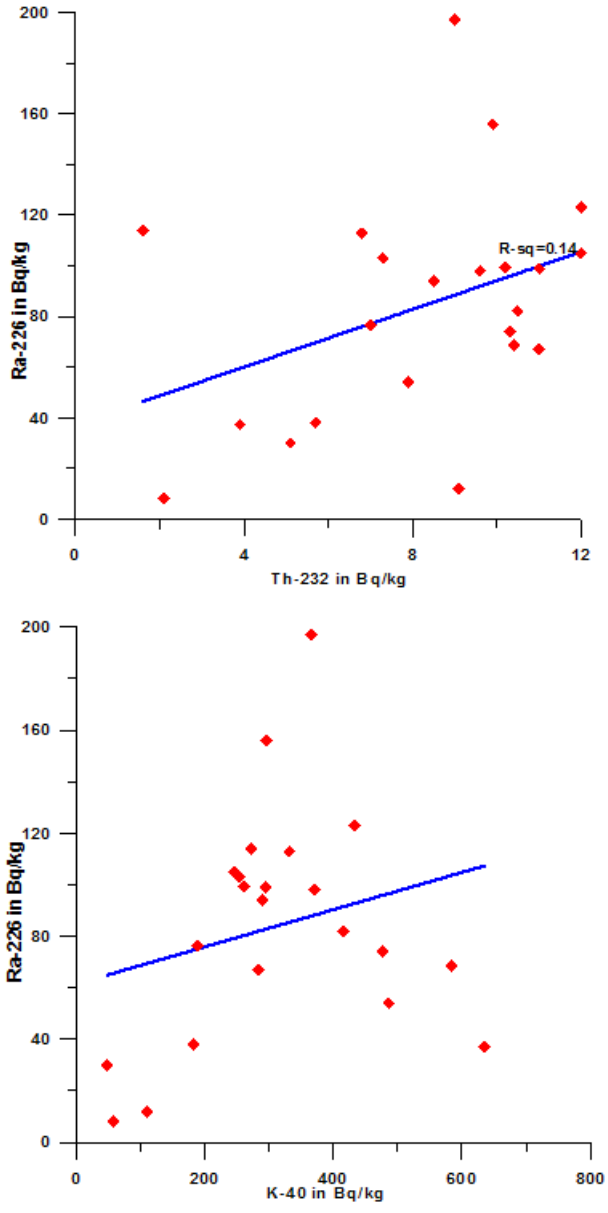

Figure 2. Correlation between ^{226}Ra and ^{232}Th and ^{40}K radionuclides

The radium equivalent activity (Ra_{eq}) of the soil samples tabulated in Table 2 ranges between 15 Bq kg^{-1} to 235 Bq kg^{-1} with average value 118 Bq kg^{-1}, which is lower than the recommended safe limit of ICRP, 370 Bq kg^{-1}. The air observed dose rate ranges between 15.3 nGy/h and 174.5 nGy/h with average value 93.0 nGy/h for outdoor. While for indoor; ranges between 29.0 nGy/h and 283.9 nGy/h with average value 167.4 nGy/h. The H_{ex} values are less than one in all samples, which is in

agreement with equation (3). However, in the case of H_{in} ; there are four sample exceeded unity with small amount in disagreement with equation (4). The annual effective outdoor and indoor gamma ray dose rates calculated in the study area ranges from 0.093 to 0.861 mSv/y and 0.142 to 1.300 mSv/y with respective mean values of 0.524 mSv/y and 0.823 mSv/y. These results are higher than the average worldwide value 0.56 mSv/y but still less than the action level of 3 - 10 mSv/y according to ICRP [15].

Table 2. Values of ^{226}Ra, ^{232}Th and ^{40}K hazard indices for soil samples of selected locations in Basrah Governorate

S.N.	Ra_{eq} Bq/kg	H_{ex}	D_{out} nGy/h	E_{out} mSv/y	H_{in}	D_{in} nGy/h	E_{in} mSv/y
1a	103	0.545	90.6	0.111	0.728	172.5	0.846
1b	191	0.759	127.6	0.157	1.180	246.9	1.200
1c	122	0.584	98.7	0.121	0.784	189.2	0.929
2a	59	0.300	50.2	0.062	0.404	95.8	0.470
2c	135	0.706	118.3	0.145	1.060	228.1	1.100
2d	41	0.301	49.7	0.061	0.450	95.2	0.467
3a	33	0.310	49.9	0.061	0.343	92.7	0.455
3b	131	0.536	174.5	0.856	0.900	111.0	0.816
4b	100	0.442	73.9	0.091	0.649	142.0	0.697
5b	146	0.564	95.7	0.117	0.869	185.7	0.911
5c	87	0.343	61.0	0.075	0.444	118.9	0.584
5d	99	0.467	79.7	0.098	0.613	153.0	0.751
6b	139	0.681	112.9	0.139	0.966	215.8	1.050
6c	132	0.605	101.0	0.124	0.874	193.8	0.951
7a	135	0.410	71.2	0.087	0.718	140.7	0.691
7b	124	0.595	101.3	0.124	0.781	194.3	0.953
9a	15	0.093	15.3	0.019	0.114	29.0	0.142
10a	138	0.611	102.9	0.126	0.878	198.0	0.971
10b	126	0.552	92..8	0.114	0.808	178.7	0.877
11c	170	0.759	127.5	0.156	1.090	245.2	1.200
12a	235	0.861	145.8	0.179	1.300	283.9	1.300
12b	126	0.601	101.2	0.124	0.825	193.9	0.951
Max	235	0.861	174.5	0.856	1.300	283.9	1.300
Min.	15	0.093	15.3	0.019	0.114	29.0	0.142
Average	118	0.524	93.0	0.168	0.758	167.4	0.823

5. Conclusion

The measured activity concentrations of ^{232}Th and ^{40}K in the soil samples of selected location in Basrah Governorate are lower than world level reported by UNSCEAR. However, the concentrations for ^{226}Ra are found to be higher than the worldwide mean value in small amount. This is may be related the effect of dust which contains some radioactive material fallout during the previous wars in the area. The results obtained from external hazard are less than unity, while in the indoor hazard there are some locations has value higher than unity. The annual effective doses for outdoor and indoor are less than the action level of ICRP. Week correlation has been found between ^{226}Ra and both ^{232}Th and ^{40}K, which indicates that one can't depends on the measurement of one parameter to determine the other.

Hence, the achievement of this work is that; soil taken from these locations in Basrah Governorate can be deal with and used as a construction material without posing any significant radiological threat to the occupiers.

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